

Corrosion

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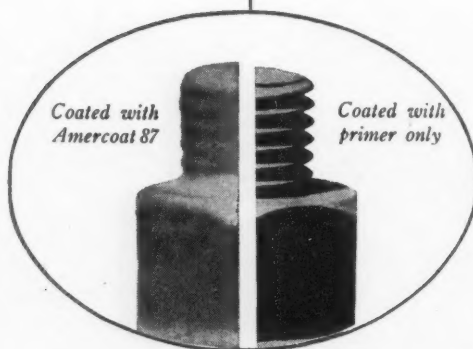
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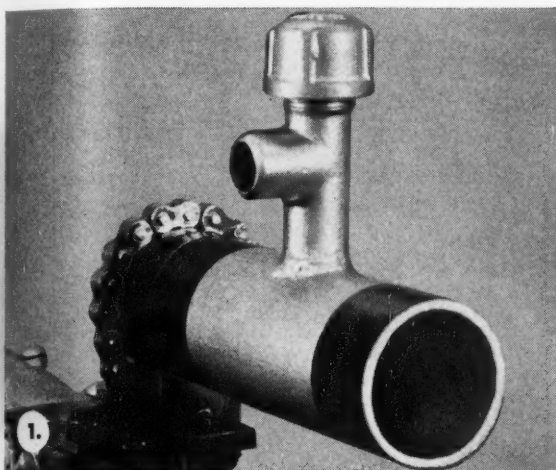
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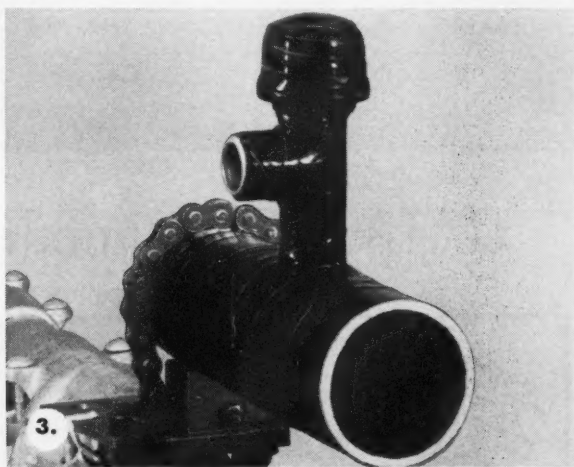
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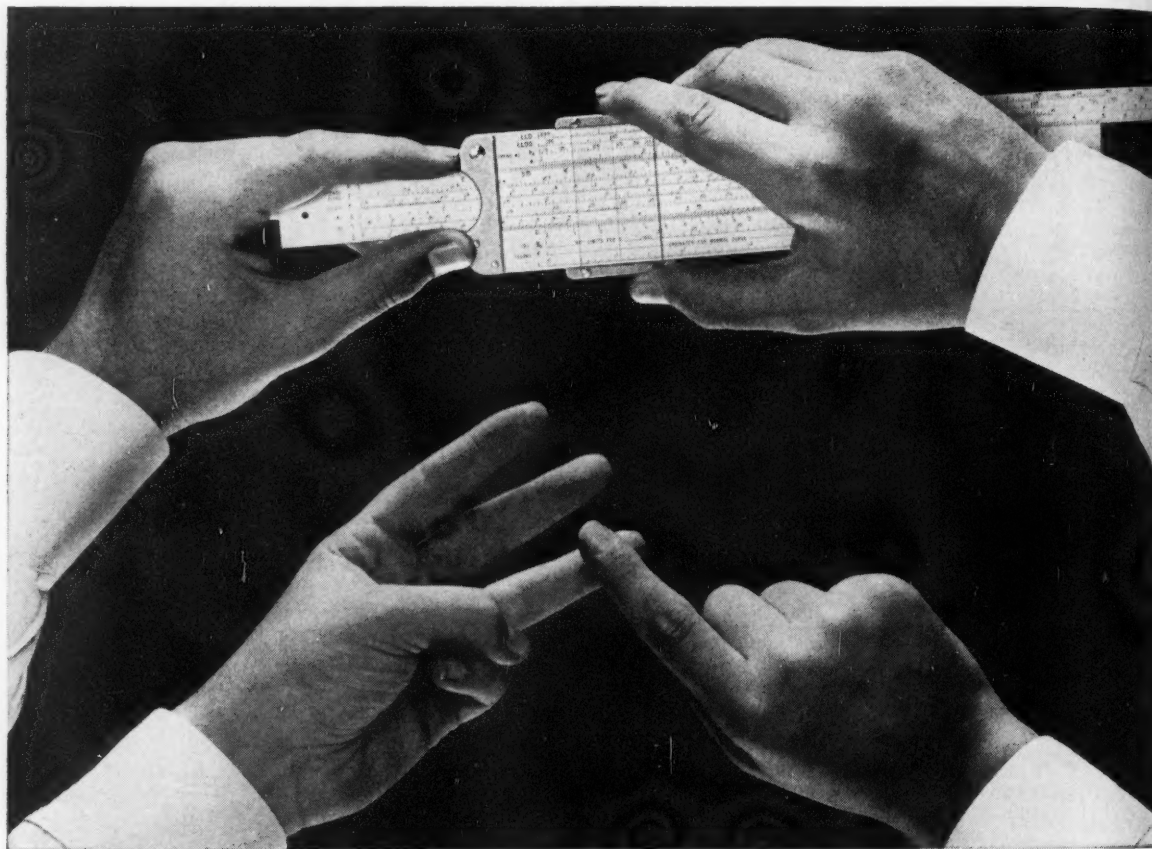
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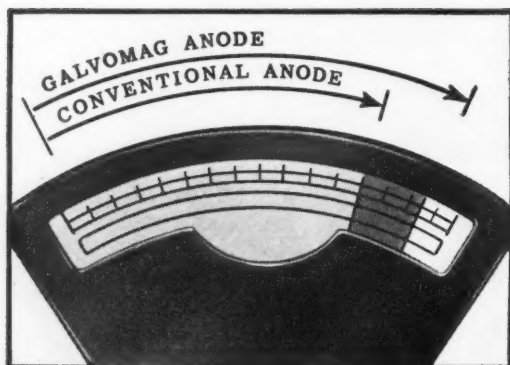
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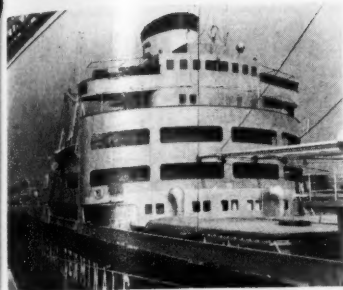
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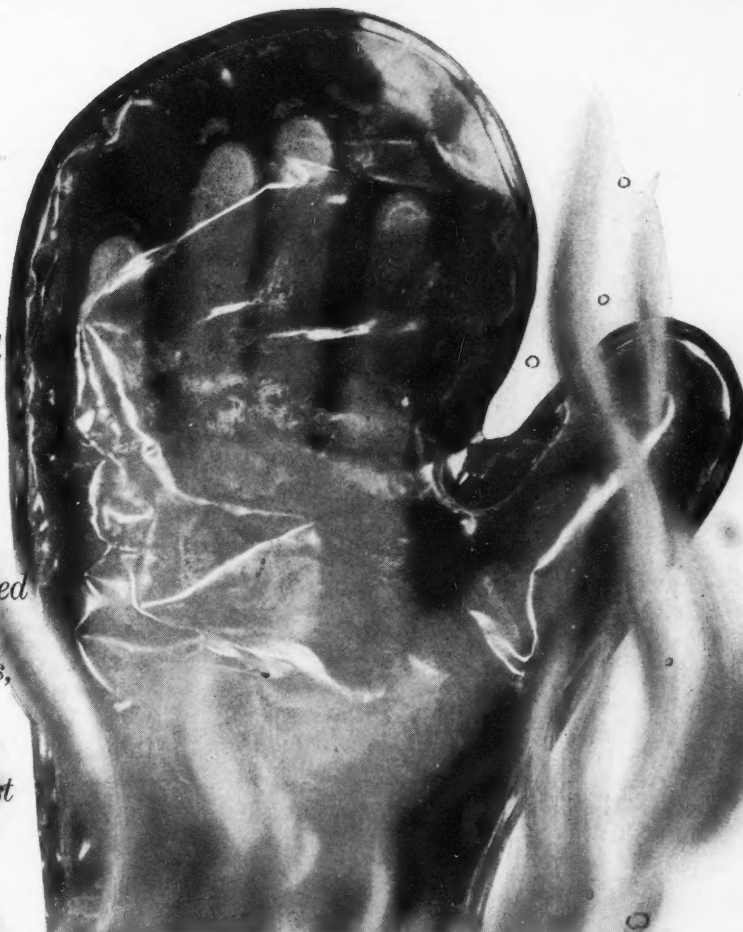
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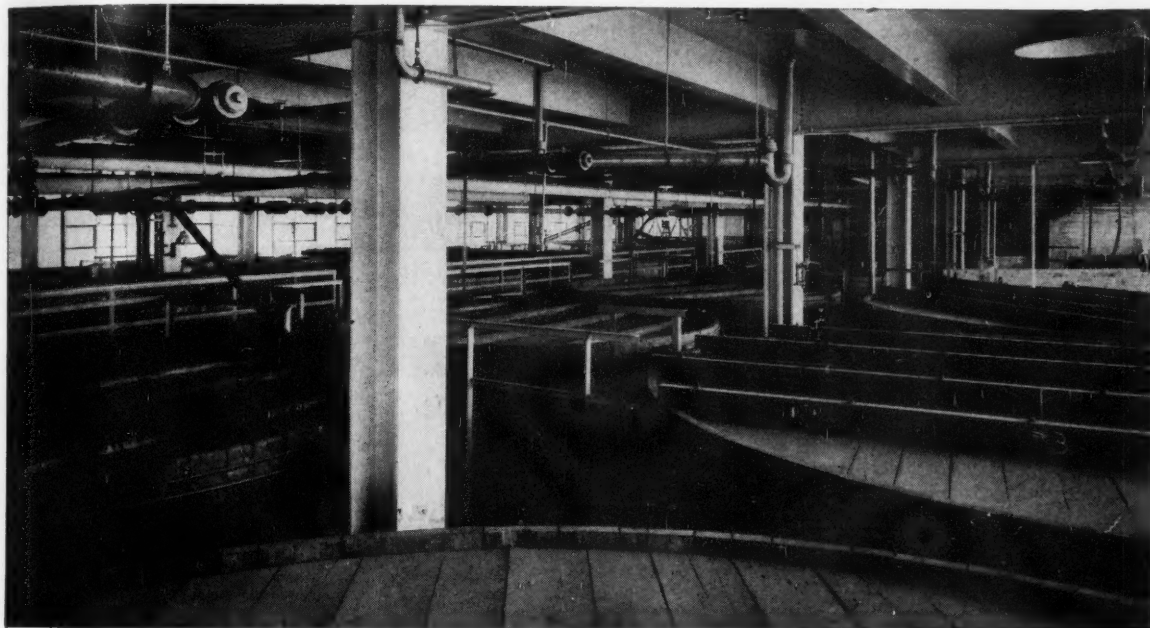
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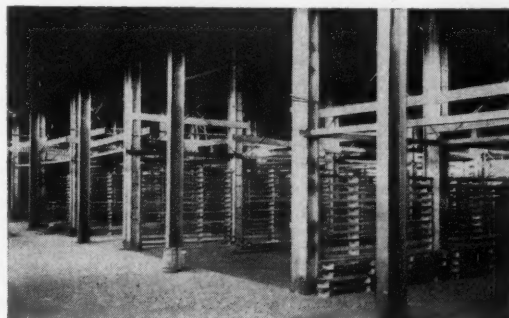
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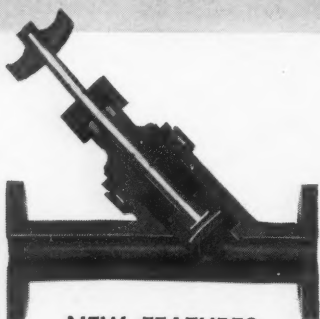
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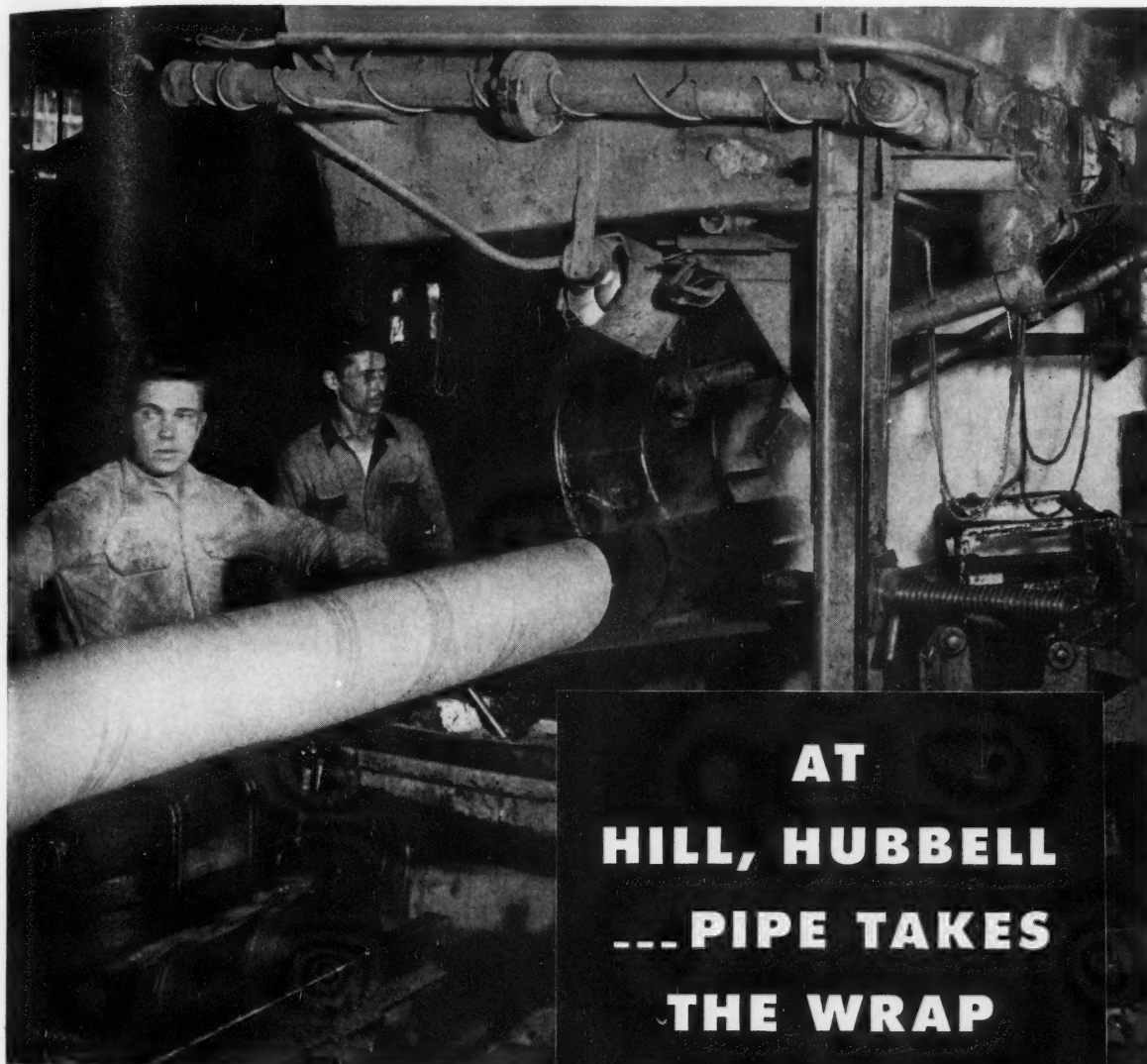
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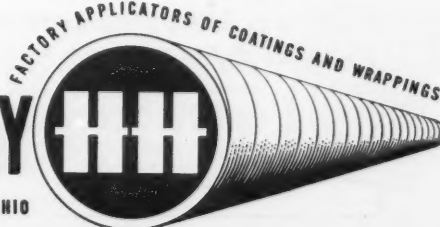
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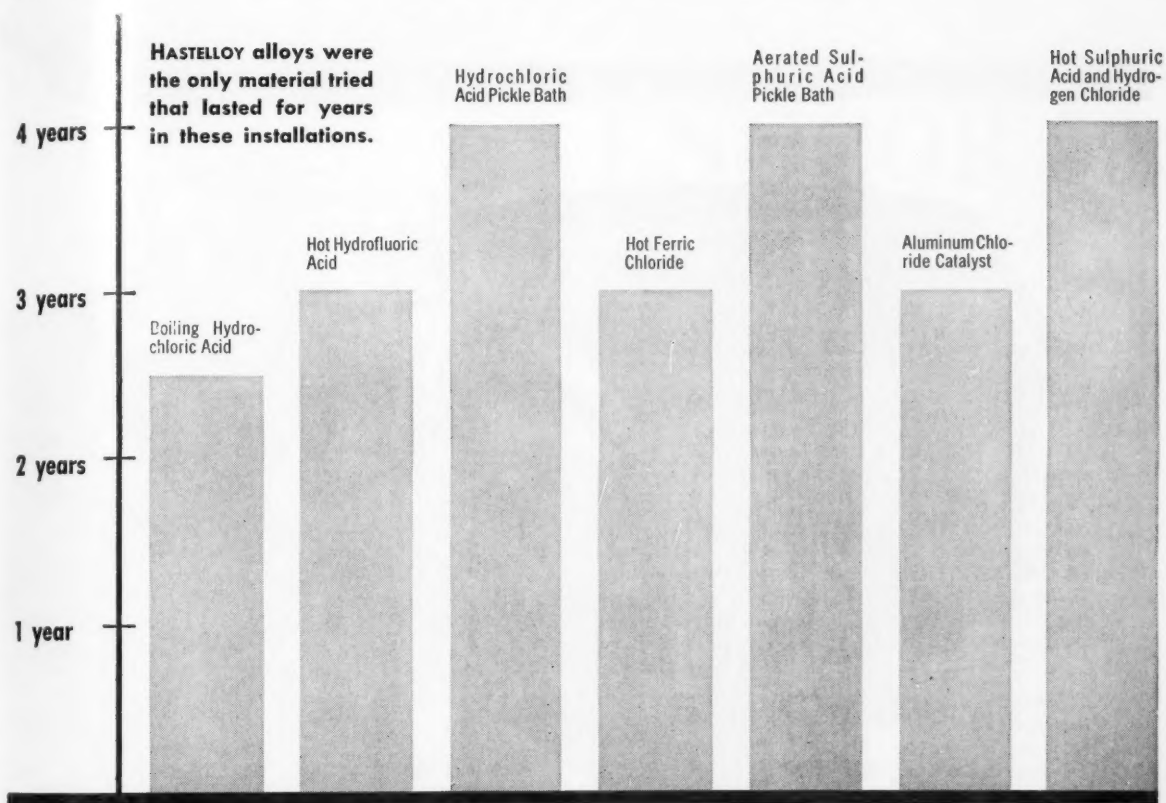
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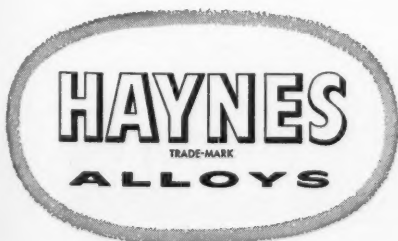
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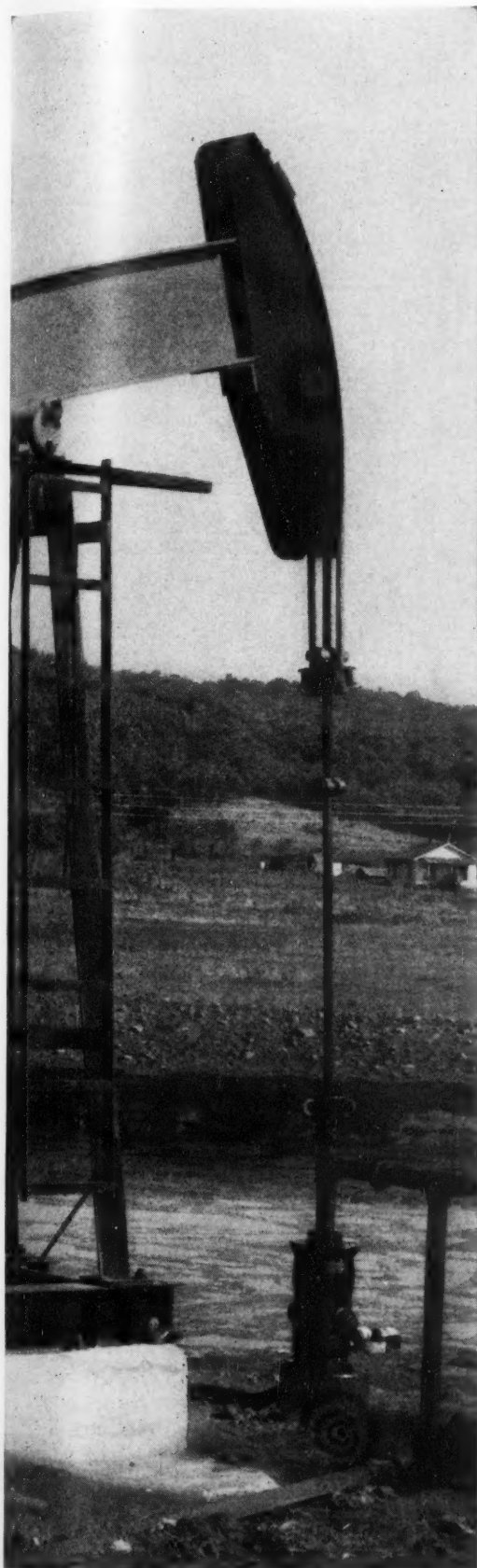
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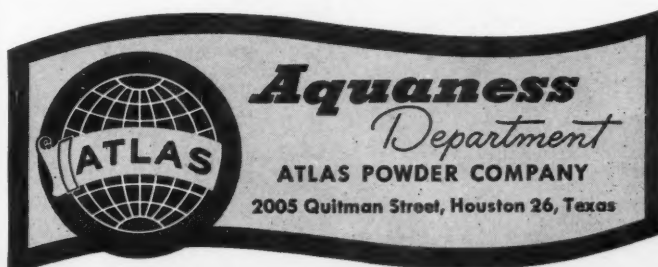
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A Laboratory Method for the Evaluation of Oil Production Corrosion Inhibitors*

By DAVID B. BOIES*

Introduction

THE CORROSION of tubing, sucker rods, and other equipment by oil well fluids has long been recognized as a serious problem. Various methods of controlling this corrosion have been tried, one of the most successful being the use of corrosion inhibitors introduced into the well.

One of the difficulties in the development of corrosion inhibitors for this purpose is the length of time and the uncertainty connected with field evaluation of a new treatment. Rapid methods of field evaluation, such as the determination of iron in the produced water and coupons at the well-head, may give indicative results within a relatively short period of time. More reliable methods, such as observation of maintenance costs, may take a year or longer. Therefore, it is obviously desirable to have a simple test which can be used to screen proposed inhibitors and act as a guide to their selection for field evaluation. Several methods have been described for such laboratory evaluation.¹⁻⁸

It is the purpose of this paper to present a test method which is simple enough for rapid screening of proposed inhibitors, yet versatile enough to allow evaluation of the effect of several variables on the performance of the inhibitor.

Experimental Method

General Objectives

In setting up a laboratory test to screen materials for field use, simplicity and speed must be balanced against versatility and duplication of field conditions. Actual well conditions vary to such a degree from field to field, and even from well to well, as to make it impossible to set up "typical" field conditions. It was felt, however, that the better the correlation of laboratory conditions with those found in the field,

Abstract

A test method used to screen and evaluate oil production corrosion inhibitors is described. Laboratory conditions are made to approximate field conditions as closely as possible with 20 ga mild steel (SAE 1010) as the test specimen. The effects on inhibitor performance of such variables as temperature, oil-brine ratio, aromatic content of oil blend, and composition of gas phase are shown graphically. 2.3.4

the greater would be the probability of correlation of laboratory and field results. Therefore, it was decided to make the test versatile enough so that as many of the conditions as possible could be varied to meet the demands of the application being studied.

Test Procedure

The test procedure used to meet these objectives is pictured in Figure 1. The test was run in a covered beaker, with the desired oil and brine used as the test fluids. The agitated mixture was deaerated by bubbling with carbon dioxide for one hour, and then carbon dioxide and/or hydrogen sulfide were bubbled through the fluids for the duration of the test. After another hour, the inhibitor was added, and one-half hour later, the specimen was inserted. The agitation was continued throughout the test. After 16 hours, the test specimen was removed, cleaned, reweighed and the corrosion rate calculated in mpy. A blank test, with no treatment was run with each series and the effectiveness of the treatment reported as percent protection. The total time required was such that one laboratory technician could run 20 tests a day.

Test Equipment

The test equipment is shown in Figures 1 and 2. A description is given below of the equipment used.

Container. The container used was a 400 ml tall form Berzelius type beaker. A hard rubber cover was

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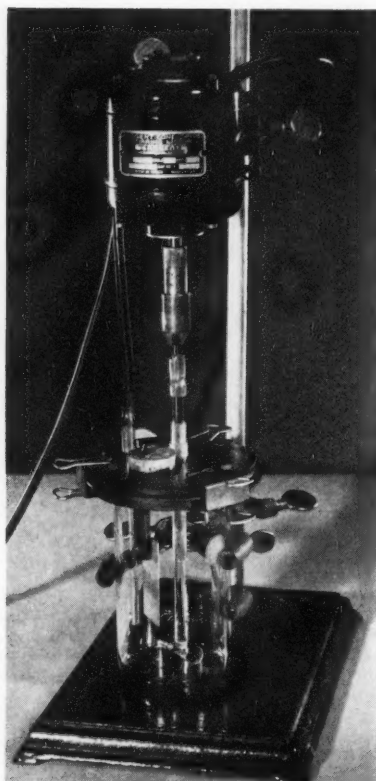


Figure 1—Corrosion test apparatus.

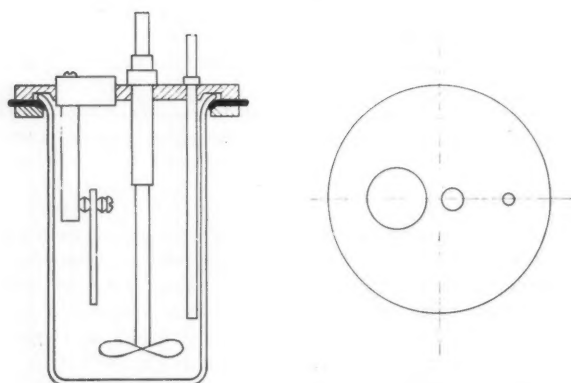


Figure 2—Oil production corrosion inhibition test unit.

clipped into position with a retaining ring and a rubber gasket. This cover had holes for the introduction of the specimen holder, the stirrer sleeve, and the gas delivery tube. The beaker was immersed in an oil bath if elevated temperatures were desired.

Agitator. The agitator used was a glass stirrer which was placed inside a glass sleeve in the cover. The propeller had two tear drop shaped blades, $\frac{1}{2}$ inch long, developing a downward thrust. The agitator was operated at 1725 rpm.

Gas Supply. Carbon dioxide (bone dry grade containing less than 0.001 percent oxygen) and hydrogen sulfide (99.9 percent grade) go through a mixing

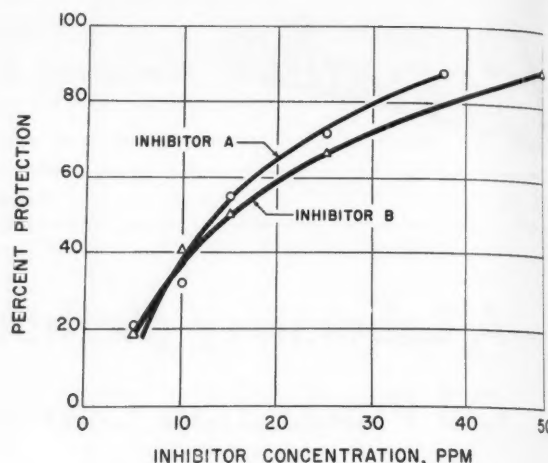


Figure 3—Corrosion test results with two inhibitors.

TABLE 1—Specifications of Oils Used in Tests

Property	Virgin Gas Oil	Aromatic Oil
API grav. at 60 F.	39	38
Initial Boiling Point	382	470
50 Percent Point	487	558
Final Boiling Point	624	690
Percent Aromatic	16	50

chamber and a manifold to the gas delivery tubes placed through the covers of the individual test containers. The gas was bubbled through the test fluids at a rate of 110 ± 20 ml per minute.

Test Specimen. The test specimen was 20 ga mild steel (SAE 1010), 1 inch by 2 inches. It was sand-blasted and weighed to the nearest 0.1 milligram. It was supported on a hard rubber holder attached to a cork in the beaker cover.

Test Fluids. The test fluids may be varied depending on the well conditions being studied. The brine used for the tests reported here was a synthetic brine having the following composition:

NaCl	25,000 ppm
CaCl ₂	4,500 ppm
MgCl ₂ ·6H ₂ O	4,500 ppm
Na ₂ SO ₄	2,500 ppm

The oils used were a No. 2 virgin gas oil and an aromatic oil, having the specifications given in Table 1. They were purified by shaking with activated alumina for two hours, and filtering through Fuller's earth, to adsorb polar compounds present. This procedure was found to improve the reproducibility of the test.

Laboratory Results

Testing of Inhibitors

Figure 3 gives the results obtained with two different high molecular weight organic corrosion inhibitors, (A), in an oil carrier, and (B), in an aqueous carrier. The results shown in Figure 3 use a 9:1 volume ratio of brine to gas oil, and a 1:1 volume

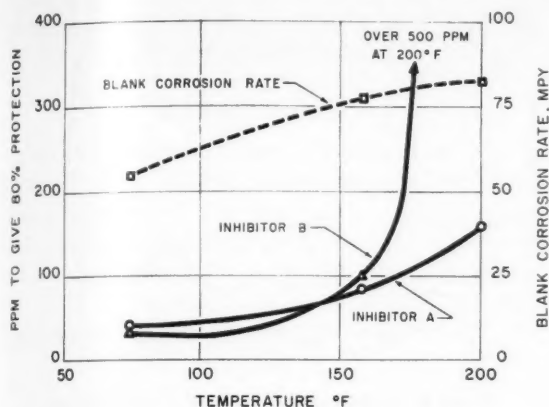


Figure 4—Effect of temperature on the performance of two inhibitors.

ratio of H_2S to CO_2 , at 75 F. Percent protection is plotted as a function of inhibitor concentration. The inhibitor concentration is given as ppm based on the total test fluid volume. The test normally is satisfactorily reproducible (± 10 percent) where either the corrosion rates or the percent protection are high. Where only partial protection is obtained, it is advisable to average the results of three or four tests to obtain an accurate figure.

Effect of Variables on Inhibitor Performance

Temperature. Figure 4 shows the effect of temperature on the performance of inhibitors A and B, using 1:1 ratio of brine to gas oil and a 1:1 ratio of H_2S to CO_2 . The concentration necessary to give 80 percent protection was determined from plots similar to Figure 3. The blank corrosion rate (i.e., without treatment) in mpy (mils per year) also is given. Both the blank corrosion rate and the amount of treatment necessary increased with increasing temperature, with inhibitor B being much more severely affected by high temperatures than A.

Oil-Brine Ratio. Figure 5 shows the effect of varying the oil-brine ratio on the performance of the inhibitors. The oil phase was again the No. 2 gas oil, the temperature was 75 F, and the CO_2 to H_2S ratio was 1:1. As can be seen, using inhibitor A, slightly less treatment was required as the percentage of brine was increased while with inhibitor B more treatment was required. The blank weight loss increased as the amount of brine increased.

Type of Oil. Figure 6 shows the results using blends of the No. 2 gas oil and the aromatic oil. Both inhibitors protected at lower dosages as the aromatic content of the oil blend was raised. The blank weight loss also was less for the higher aromatic content blends.

Composition of Gas Phase. The effect of varying the composition of the gas phase is shown in Figure 7. The oil phase was the No. 2 gas oil, the oil brine ratio was 1:1, the temperature 75 F. The major effect was the increase in the corrosion rate when hydrogen sulfide, or a 1:1 mixture of hydrogen sulfide

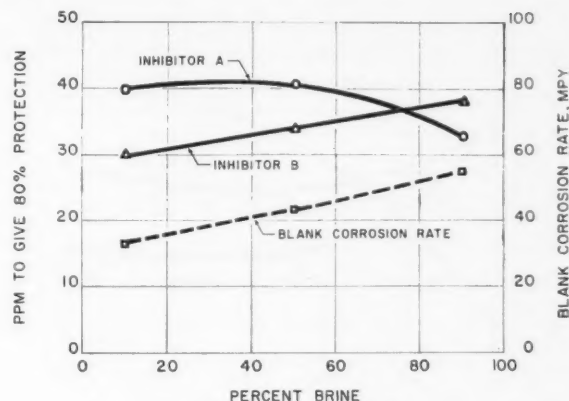


Figure 5—Effect of oil-brine ratio on inhibitor performance.

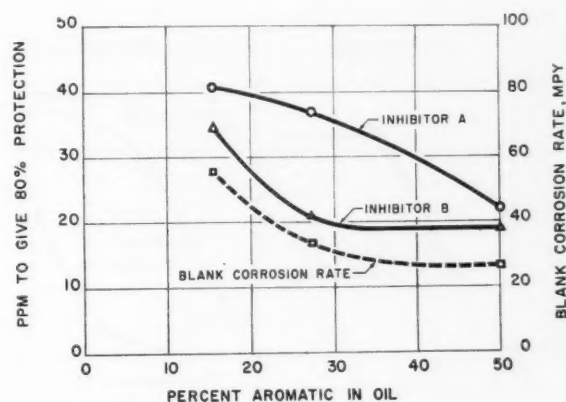


Figure 6—Effect of type of oil on inhibitor performance.

and carbon dioxide was used, as compared with carbon dioxide alone. Slightly more inhibitor was required to give 80 percent protection when carbon dioxide was used alone, but this may be because the inhibited corrosion rates are being compared to a much lower blank.

Comparison With Results from the NACE Screening Test

Results using the test method discussed here and the NACE screening test are presented in Figure 8. Inhibitors C and D are high molecular weight organic inhibitors. Inhibitor C was tested in an oil carrier, and inhibitor D was tested both in oil and aqueous carriers. It can be seen that inhibitors C and D gave similar results when tested by the dynamic method reported here. However, when tested by the NACE screening test, inhibitor C gives good protection, while inhibitor D gives poor protection when used with an oil carrier, and only fair protection when used with an aqueous carrier (and hence added to the brine phase). These differences between the NACE screening test and the dynamic test results are considered to be due mainly to the static condition and the lack of equilibrium between the two phases of the NACE screening test.

Field test results indicate that inhibitors C and D

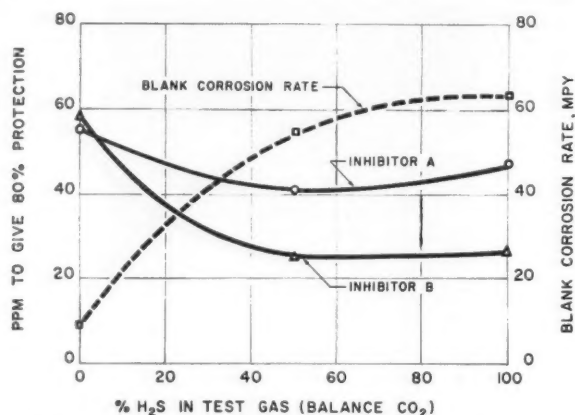


Figure 7—Effect of gas phase composition on inhibitor performance.

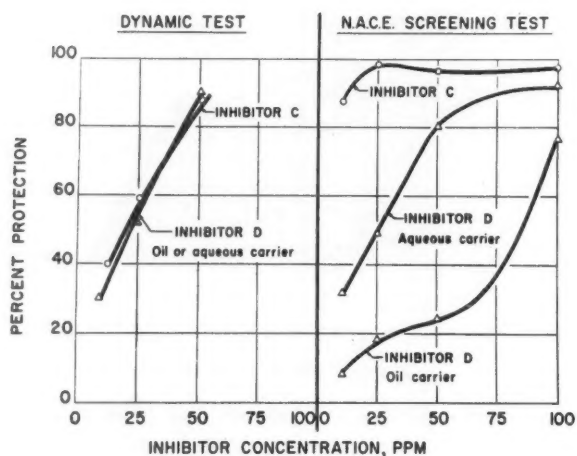


Figure 8—Comparison of dynamic test with results from the NACE screening test.

TABLE 2—Performance of Inhibitor A in a Sour West Texas Field

Concentration	Number of Wells	
	Protecting	Corroding
61—107 ppm.....	5	1
30—58 ppm.....	0	3

TABLE 3—Performance of Inhibitor A in a Sour Kansas Field

Concentration	Number of Wells	
	Protecting	Corroding
23—60 ppm.....	10	2
12—20 ppm.....	0	4

are both good corrosion inhibitors, and that they are effective over approximately the same concentration range.

Field Results

The test has proved to be quite successful in differentiating between those inhibitors which have and have not proved to be generally satisfactory for field

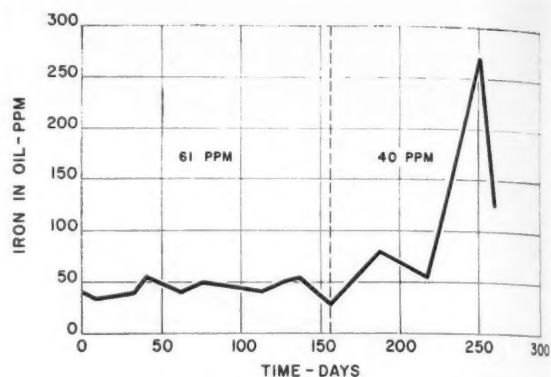


Figure 9—Results with inhibitor A in a sour Texas well.

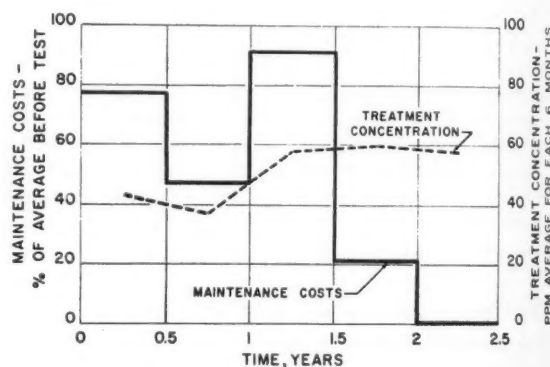


Figure 10—Results with inhibitor A in a sour Kansas well.

application. Inhibitor A, which shows good results under a variety of laboratory conditions also has been quite satisfactory in field use. It was tested in nine wells in a sour West Texas field, using iron-in-oil determinations to evaluate the effectiveness of the inhibitor. In these wells, inhibitor A performed as shown in Table 2. The effect of lowering the dosage in one of these wells is shown in Figure 9.

Inhibitor A also was tested in 16 wells in a sour Kansas field. Here, the inhibitor was evaluated by comparing the maintenance costs caused by corrosion over a two and one-half year period with the costs from the two years previous to the test. In these wells, inhibitor A performed as shown in Table 3.

The detailed history of one of these wells is shown in Figure 10. The well did not respond properly at treatment levels between 35 and 45 ppm, but maintenance costs were reduced very satisfactorily when the dosage was raised to 60 ppm.

In general, field results which show protection from 30 to 60 ppm with inhibitor A, are in agreement with the ranges found in the laboratory tests under the various conditions.

There is always danger in applying the results of tests under some set of arbitrary laboratory conditions to the varied conditions found in field applications. This danger may be minimized by testing under as broad a range of conditions as feasible, but

the results still must be considered as guides, the final answer lying in field performance.

Acknowledgment

The author acknowledges his indebtedness to Jerome Green and Aaron Sterlin for assistance in the development of the test method; to R. Kurle and T. A. Nordsell, who performed much of the experimental work, and to Dr. J. W. Ryznar, C. E. Johnson, Dr. J. I. Bregman, and R. G. Rydell, for their invaluable advice and suggestions.

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Any discussions of this article not published above will appear in the December, 1956 issue.

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Earth Potential or Surface Potential Gradient Tests on Buried Cables*

By DANIEL R. WERNER

Foreword

THIS PAPER has been prepared with the thought that it will serve to show what is meant by earth potential or surface potential gradient tests, uses for the method, some of its limitations, methods of making the tests, suggestions for less time consuming methods, together with a few examples of the many possible uses outlined.

The method outlined is one which has been used by the author in testing work on buried cables. The principles involved are not new but have not been combined previously into instructions for use by telephone people. Pipe line people also may find the paper interesting particularly the discussion in Section 3.3. This section concerns interference effects created on buried structures and railroads equipped with dc signaling by the installation of made ground beds too close to those structures.

1.0 General

1.1 Field of Use

1.1.1 Earth potential or surface potential gradient tests consist of the measurement of the potential difference between two or more points on the surface of the earth. These tests are useful determining the following:

- a. Location of hot spots or current loss areas along a buried structure due to variations in the moisture content of the soil or variations in earth resistivity.
- b. Location where current may be leaving a short section of wire armored cable used in a long buried cable system.
- c. Where particularly bad sections of coating exist on a structure which generally has such a poor coating that the Pearson method of holiday detection is of little use.
- d. What effect the proposed location of the made ground of a cathodic protection system will have on other subsurface structures.
- e. Exact location of magnesium anode installations.
- f. Exact location of point type anodes used with rectifier installations.
- g. Location of long pipes in made grounds used with rectifier installations.
- h. Approximate location for the installation of current flow test leads to measure the maximum amount of current discharge.
- i. What effect the proposed location of the made ground of cathodic protection system may have on a nearby railroad. Only those railroads equipped with direct current signaling or which will be equipped with direct current signaling need be considered.
- j. To what extent a known buried bare structure or a poorly coated structure will affect another structure at points of crossing.
- k. Location of unknown crossing structures which are disturbing the earth gradient.



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Abstract

Earth potential or surface potential gradient tests, their types, uses and limitations are discussed. Topics covered include range of potentials, selection of areas for tests, installation of remedial measures on buried telephone cables, determination of buried structure location and meter circuits for measuring potential gradients. Data are given also on hot spot areas, changes in insulation resistance of the covering on a buried cable and interference effects on other buried structures and railroads from cathodic protection installations.

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1.1.2 Although experience with the earth potential or surface potential method of testing has been very limited, it has been used successfully in practically all applications listed above. Illustrations of some actual experiences are described herein.

1.2 Basis of Method

1.2.1 The method is based on measurement of voltage drop through the earth, the measurements being made at the surface of the earth. Where a change in structure-to-earth potential is measured by means of a half cell placed on the surface of the earth over a structure at different points along the structure it frequently is assumed that these changes in potential are caused by current picked up or discharged from the buried structure. This is not always the case. When a metallic structure is buried in the earth it normally will affect the earth potential gradient in its vicinity. Pieces of metal in the earth particularly around splices may cause large potential differences within a very small area. Brass hardware cloth which is sometimes used around buried cable splices causes large changes in potential, for example.

1.2.2 Variations in the earth potential gradient along the surface of the earth may occur even though there is no buried structure present. However, when variations in earth potential gradient are observed

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from measurements made over a buried structure and other measurements are made which indicate that the structure is picking up or discharging current from the earth in the same area, it would appear that the test results are valid. The method of determining current pickup and discharge is covered in Paragraph 2.4.4 and Table 1.

1.3 Range of Potentials

1.3.1 The range of potential difference along the surface of the earth over a structure between a current pickup area and a current discharge area has been found to be as much as 250 to 300 millivolts on pipe lines where extreme variations in earth resistivity occur. Potential differences of as little as 5 to 10 millivolts along pipe lines have been found to indicate a situation where corrosion of the pipe is occurring.

1.3.2 The range of potential difference between different points on the earth's surface may be several volts where the earth gradient is disturbed by large currents discharged into made grounds.

1.3.3 The method has not been tested over a sufficient amount of buried cable and the cable exposed to determine what order of magnitude of potential change might indicate a serious corrosion condition. In one case between Markers 23-24 of the Grand Island-North Platte "A" and "B" cables which was located by this method (Figure 1), the 10 mil thick steel tape of one of these gopher protected cables was found to be corroded open 14 years after the cable was installed. Maximum potential variation in this case was approximately 50 millivolts. The steel tape had corroded through in less than 14 years but actual time required is not known. The lead cable sheath showed no signs of corrosion although some discoloration of the lead at the $\frac{1}{8}$ -inch gap between the turns of steel gopher tape was observed. Investigation of this case was brought about by current flow tests at the approximate mile apart test points showing about 60 milliamperes and 10 milliamperes flowing toward the trouble area. Cable-to-earth potentials measured at the gas valve pipes installed at approximately half mile intervals did not indicate anything unusual.

1.4 Personnel Required to Make Tests

1.4.1 To make the surface potential gradient tests in the manner described in Section 2.0, requires two men, one to take readings and the other to advance with the roving half cell along the structure being tested. The amount of time required will depend upon the distance apart the readings are to be taken along the structure or the presence of natural or other obstructions such as corn standing in the field higher than a man's head. To plot the tests later and place data in shape for future reference will take additional time of one man.

1.5 Distance Apart the Readings Should be Taken

1.5.1 The distance the roving half cell (half cell that is moved along the surface of the earth) will have to be moved between successive readings may be from a few inches to a hundred feet depending upon the

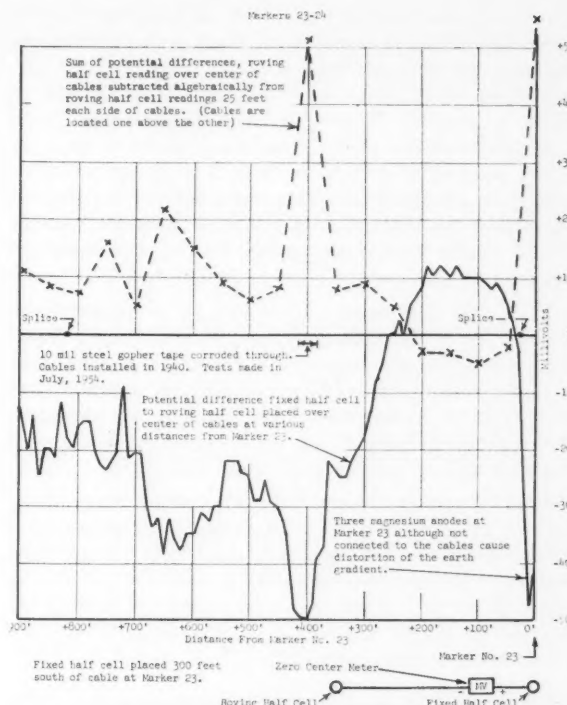


Figure 1—Earth potential gradient tests, Grand Island-North Platte "A" and "B" Cables, Markers 23-24.

TABLE 1—Determination of Current Pickup and Current Loss Areas

Analysis of half cell readings to determine current pickup and current loss areas when the roving half cell is placed first over the structure being tested then an equal distance of 4 feet to 25 feet each side of the structure being tested. The potentials given in Columns (1), (2) and (3) are to a copper-copper sulfate half cell reference. If some other reference half cell were used, different values would be obtained but the same values would result in Columns (4), (5) and (6) regardless of the type of half cell used.

Test	Potential to Roving Half Cell Placed Over Center of Structure Being Tested	Potential to Roving Half Cell Placed an Equal Distance Each Side of the Structure Being Tested		Col. (2) Minus* Col. (1)	Col. (3) Minus* Col. (1)	Col. (4) Plus Col. (5)
	(1)	Left	Right			
1	-.4	-.35	-.34	+.05	+.06	+.11
2	-.4	-.5	-.49	+.1	+.09	+.19
3	-.65	-.6	-.59	+.05	+.06	+.11
4	-.59	-.45	-.7	+.14	+.11	+.03

Interpretation of Test Results

If Columns (4) and (5) are both positive for any particular test result then current is leaving the structure to the earth.

If Columns (4) and (5) are both negative for any particular test result then current is entering the structure from the earth.

If Columns (4) and (5) are both positive and negative as in Test 4 then cross current flowing through the earth is of sufficient magnitude to be confusing.

Column (6) is the addition of Columns (4) and (5) and eliminates the confusing effect of cross currents. A positive value indicates current flow from the structure to the earth and negative value indicates current flow to the structure from the earth.

* Algebraic subtractions.

Note: The above interpretation of test results should hold good where earth resistivity is fairly uniform in a transverse direction to the line of the structure, the earth is virgin soil and does not contain any metal placed by man except the structure being tested. The presence of any other metal such as pipes and discarded cans and the like will disturb the earth gradient and render the analysis difficult or impracticable.

purpose for which the test is being made and these distances will have to be tailored by the tester making the field tests.

1.5.2 The distance the roving half cell should be moved in locating current loss or hot spot areas on telephone cables is approximately 10 feet. The reason

for this is that the jute covering on telephone cables is, in general, a uniform relatively poor insulator and the location of areas of low earth resistivity or current loss covering at least a 5 to 10-foot length of cable is desired. If the buried structure were well insulated and the tests were being made to locate a break in insulation then tests at 2 to 4-foot intervals would be required to locate such breaks because 90 percent of the voltage drop through the earth usually would occur within about ten feet of the break in insulation.

1.5.3 To determine the location of magnesium, steel or graphite anodes or anything having a small area in electrical contact with the earth may require that the roving half cell be moved only a few inches at a time if an accurate location is to be obtained. Approximate location can be obtained with the roving half cell moved at 2 to 3-foot intervals.

1.5.4 In cases where the earth potential gradient is being determined around a structure or ground bed discharging current into the earth the roving half cell may be moved from only a few feet at a time when close to a structure discharging or picking up current to a hundred feet at a time depending upon the results being obtained.

1.6 Selection of Areas for Surface Potential Gradient Tests

1.6.1 Any plan for making earth potential or surface potential gradient tests to determine current loss areas on a buried structure should be made first on a selective basis from certain indications evident, such as low wet areas, creek and river crossings, an increase towards the negative of the structure-to-earth potential, current flow on the structure where current flow points are provided and known wire armored sections of cable. These areas are the most likely areas of possible current loss. Next those areas should be covered where black loam soils are evident, followed finally by the sandy soils.

1.7 Location of Maximum Current Flow on Buried Structure

1.7.1 From the surface potential gradient tests it may be possible to obtain the approximate location of the maximum current flow on the buried structure into current loss areas. Current pickup and current loss areas may be determined from an analysis of test results as outlined in Table 1. From the limited tests made so far it has been found that a current loss area may be composed of several small areas of varying degree of current loss. Maximum current flow on the buried structure usually will occur close to the location of the first current discharge area closest to the current pickup area. This should be the point where arrangements to measure current flow on the structure should be made in connection with the installation of remedial measures.

1.8 Discussion of the Installation of Remedial Measures on Buried Telephone Cables

1.8.1 After location of the current loss areas, the

remedial measures, most probably in the form of magnesium anodes, should be installed at or near the junction of current pickup and current loss areas to drain sufficient current to reduce to zero or cause current to flow away from the current loss area. In general this should be done during the dry season for normally wet current loss areas because current flow on the cable then will probably be greatest. Current loss from the structure to earth will be prevented provided attenuation of the anode current along the metal being protected in the current loss area is less than attenuation of the galvanic current flowing. Conditions have been found in very low resistance soils where attenuation of anode current was greater than attenuation of natural galvanic current. In the latter case the installation of magnesium anodes in the manner described above will not be adequate to prevent a current loss and additional anodes will be required in the current loss area and possibly also in the current pickup area.

1.8.2 The lead sheath and steel tape of gopher protected and tape armored cables act as separate conductors insulated to a certain degree from each other with different rates of attenuation to current flow between sheath and earth and steel tapes and earth. Unless there exists in the vicinity of the current loss area a bond between steel tapes and lead sheath such as occurs at a splice or electrolysis current flow test point, the galvanic current which flows is controlled primarily by attenuation of currents along the steel tape. The same is true of wire armored cables. Therefore, where magnesium anodes are installed on gopher protected and tape armored cable the steel tape and lead sheath should be bonded together at the anode connection points. Lead sheath and steel tape also should be bonded together on these cables at each end of the standard 30-foot section of cable bridged by the electrolysis current flow test leads.

1.8.3 In the case of modified tape armored cable, lead sheath and steel tapes may be considered from a corrosion standpoint to be in direct contact with each other. Although loss of steel tapes in gopher protected and tape armored cables may not be too serious because of some insulation between the lead sheath and steel tapes, this is not true of modified tape armored cables. Modified tape armored cables together with jute protected cables are the presently used standards for buried long distance cables.

1.8.4 Fundamental principles are that magnesium anodes should be installed as close as possible to the location where the current is naturally trying to go and that surface potential gradient measurements are essential to locate these areas.

1.8.5 Cables with relatively poor insulation to earth provided by jute coverings have a rather high attenuation to currents flowing on them, making it necessary to locate the magnesium anodes as close as possible to the current loss areas. The relatively poor insulation also makes it difficult to apply economically a sufficient number of evenly spaced magnesium anode installations to affect cable-to-earth

potential sufficiently to prevent current loss in the current loss areas. It is therefore essential that current loss areas be located and that magnesium anodes installed as close to those points as possible.

1.8.6 A knowledge of the location of current loss areas and the amount of current being discharged does not necessarily indicate that remedial measures are justified economically. Other factors must be considered, such as length of cable over which the current is being discharged, expected life with such current discharge, replacement cost of the cable, cost of remedial measures, carrying charges on the remedial measures and the possibility of new developments making the cable obsolete. All these factors will not be discussed here.

1.8.7 It appears important to make a certain number of periodical inspections at locations where current loss is occurring on cables which have been in service for 10 years or more. These inspections should be made first at locations where the greatest change in potential gradient occurs, and then at locations where the potential gradient change is not as great. Earth resistivity measurements should be made in both current loss areas and adjacent current pickup areas, because there may be some relation between the earth potential gradient change and the change in earth resistivity from current pickup to current loss areas. There also may be some relation between the corrosion rate and the earth resistivity in current loss areas. Such relations should be useful in predicting possible seriousness of a current loss or hot spot areas without resorting to exposing the cable.

2.0 Method of Making Surface Potential Gradient Tests Along a Buried Structure

2.1 Locating Buried Structure

2.1.1 It is essential that the location of the buried structure be known so that the half cell which is moved along the cable (called the roving half cell) may be placed directly over the buried structure. Location of the buried structure may be determined by connecting an audible tone source between the structure and a temporary made ground consisting of driven ground rods or the equivalent about 50 to 100 feet from the structure. An alternating current field is set up about the buried structure which is detected by an exploring coil locator and the voltage amplified by an audio frequency amplifier. When the exploring coil locator is held vertically directly over the structure being located, no tone will be heard in the receiver connected to the amplifier. If the coil is moved two or three inches either way from the vertical a tone will be heard in the receiver.

2.1.2 A satisfactory audible tone source is the Western Electric 20-C Test Set or the Signal Corps I-51A Test Set. Tests made on the output of one of these sets is shown in Figure 2. Best results are obtained if the structure-to-made ground resistance is from 3 to 20 ohms, although good results will be obtained with circuit resistance as high as 100 ohms.

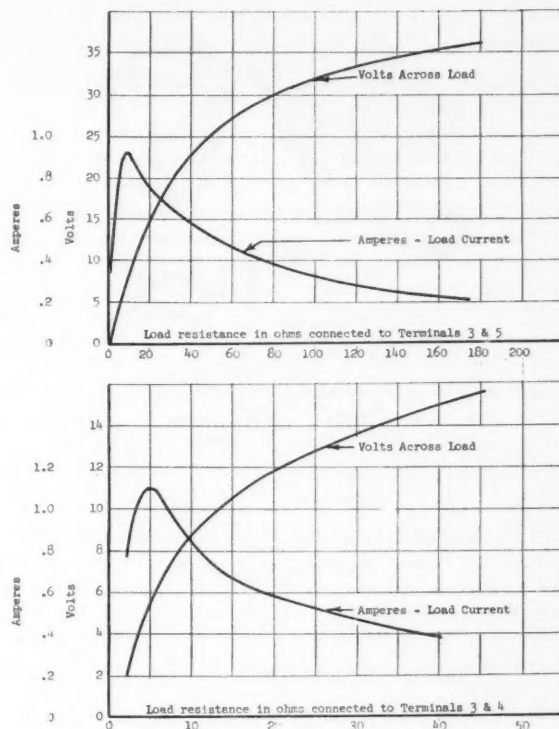


Figure 2—Tests on Signal Corps set I-51A.

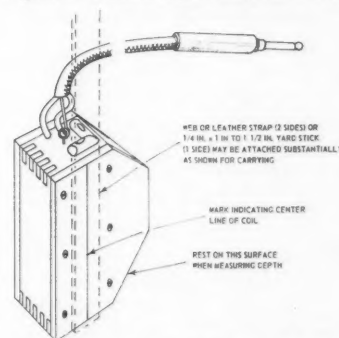


Figure 3—One coil locator test set.

The maximum output current of 1.0 to 1.1 amperes is realized with a circuit resistance of 3 to 7 ohms.

2.1.3 An exploring coil locator which has been found satisfactory is the Western Electric 93A Test Set shown in Figure 3. This locator consists of a single coil, surrounding a laminated silicon core, fixed in a small wooden box, $2\frac{3}{16}$ by $3\frac{1}{16}$ by $4\frac{3}{4}$ inches, one side of which is at a 45 degree angle with the base. The coil is held vertically to determine the location or path of the buried structure and at 45 degrees to one side on the level to determine the depth. The horizontal distance between the path of the buried structure and the side location of the coil when no tone is heard in the receiver will be the vertical depth of the structure.

2.1.4 An amplifier designed to work in conjunction with the 93A Test Set is the Western Electric 147B amplifier. When the 147B amplifier is furnished in a carrying case complete with 723A receiver, cord

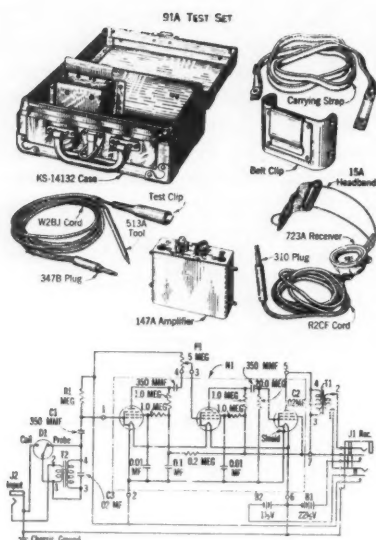


Figure 4—91A test set.

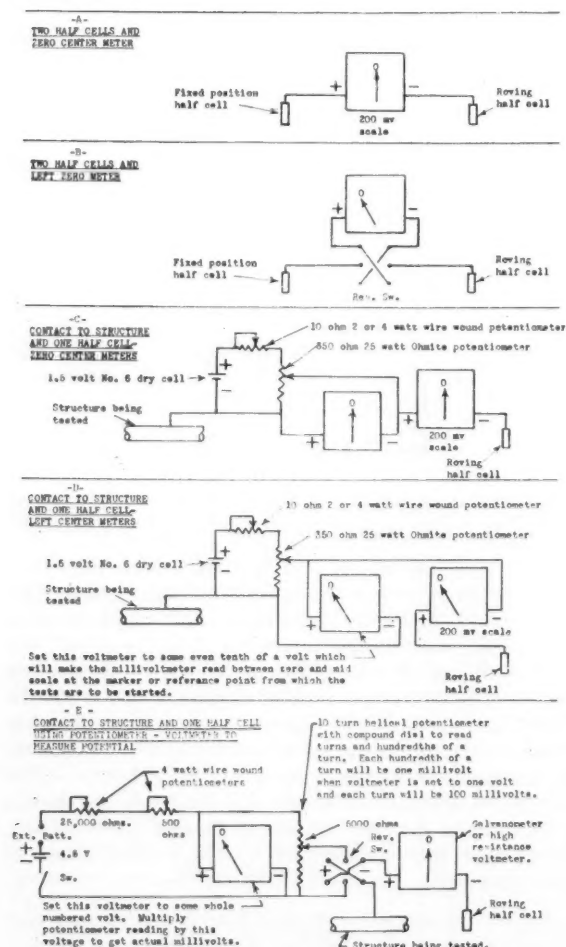


Figure 5—Meter circuits for earth potential gradient testing. (Millivolt meter should be at least 200,000 ohms per volt.)

and plug and a 513A probe, the set is coded as the 91A Test Set. An illustration of the 91A Test Set is shown in Figure 4. The carrying case was designed to have space to store a 93A Test Set also. The amplifier should be set at a probe when used with the 93A Test Set (exploring coil locator). The carrying case measures 9 by 11¼ by 5⅜ inches. The 147B amplifier is about the size of a large 4½ volt "C" battery using three "D" size flashlight cells. The amplifier weighs 1¼ pounds. The amplifier can be carried by clipping over the trouser belt or it may be slung over the shoulder by means of the carrying strap supplied with the amplifier.

2.2 Meter Circuits for Measuring Potential Gradients

2.2.1 There are several ways in which the potential difference can be measured between a fixed position half cell or equivalent and the roving half cell (half cell that is moved along the structure being tested). Figure 5 shows four circuits (A, B, C and D) which can be employed using direct operating meters. Potentiometer-volt-meters (Circuit E on Figure 5) will be found to be more accurate, particularly in dry high earth resistivity soils. However, the potentiometer-voltmeter will be somewhat slower than the direct operating meters.

2.2.2 In circuits A and B, the potential is measured between the roving half cell and a half cell in a fixed position, the latter being either over the structure under test or 100 to 150 feet either side of this structure. Two copper-copper sulfate half cells are used connected to the low millivolt scales of a high resistance voltmeter. The desired potential differences are obtained but there is no definite reference potential. These are the simplest circuits to use and do not require any electrical connection to the structure along which the tests are being made.

2.2.3 In Circuits C and D, the structure-to-earth potential at some point is used as a reference. There is considerable natural difference in potential between the structure being tested (iron, steel or lead) and the copper-copper sulfate half cell so that this voltage must be for the most part cancelled before small variations in potential can be read as millivolts on the voltmeter. The magnitude of the voltage cancelled should be recorded. It is necessary that this cancelling voltage be held at some known value and recorded in conjunction with the millivolts read. Total voltage will be the sum of the cancelling voltage and millivolts read, giving due regard to polarity.

2.2.4 The potentiometer-voltmeter also can be used to measure small millivolt changes when there is a large potential difference between the structure being tested and the reference ground. Circuit E in Figure 5 shows a simple arrangement for a potentiometer-voltmeter. Voltage can be read to one millivolt when the voltmeter is set to one volt, two millivolts when the voltmeter is set to two volts, three millivolts when the voltmeter is set to three volts and so on. Actual voltage in millivolts will be the reading on the potentiometer times the voltmeter reading. The voltmeter should be set to a whole numbered volt. There are potentiometer-voltmeters

on the market which will permit more accurate absolute value to be measured repeatedly. The one illustrated can be assembled readily from standard parts and will be sufficiently accurate for earth potential gradient measurements. Its accuracy is limited primarily to the accuracy to which the voltmeter can be set. One volt can be read more accurately on a voltmeter having a full scale reading of one volt than on a voltmeter having a full scale reading of 10 volts.

2.2.5 In the figures of surface potential gradient tests included here either Circuit A or a circuit similar to Circuit C was used except that the cancelling voltage was not measured in the latter case. The circuit used is shown on each figure.

2.3 Wire and Wire Reel

2.3.1 It will be necessary to pull a wire over the surface of the earth for the greatest distance over which it is expected to measure the potential change along the surface of the earth. For distances of 3000 to 6000 feet the wire should be light in weight, of high tensile strength and have a smooth surface so that there will be little friction developed in pulling it along the surface. The end of the wire should be equipped with a type of terminal which will not catch in the crotch of weeds but yet light enough so it will not whip around a weed in case of a sudden pull when wire is rewound on the reel. Resistance of the wire is not too important where potentiometer-voltmeters are used to measure the potential differences. Experience has shown that a three conductor wire should be used so that one pair of the wires may be used for a talking circuit.

2.3.2 The reel for the wire should be large enough to hold the maximum amount of wire plus a little margin. The reel should rotate easily, preferably on ball bearings. It should be equipped also with a brake controlled by the motion of the wire as it is pulled off the reel to prevent the reel continuing to turn and prevent tangling or kinking when the pull is stopped. This has been found necessary to relieve the meter reader of the necessity of watching the reel to prevent wire tangling. The reel should have provision for anchoring it down to prevent a sudden pull on the wire from tipping or otherwise throwing the reel out of line. The connection to the wires at the center of the reel should be brought out on slip rings so that it will not be necessary for the meter reader to connect and disconnect wires from the reel as the roving half cell is advanced to a new position.

2.4 Testing Procedure

2.4.1 The path of the buried structure must be known and it may be determined using the equipment outlined in Section 2.1. The path of the buried structure may be staked out ahead, or it may be located as each change is made in the location of the roving half cell. The audible tone source should be located where the metering equipment will be set up. The meter reader should be able to turn the tone

source off while he is reading the meters to conserve battery power.

2.4.2 The meter reader and the man advancing along the path of the cable with the roving half cell should be equipped with a means of communication because it is expected that as much as 5000 feet of buried structure may be tested with one set up. Direct communication between the meter reader and the man moving along with the roving half cell is necessary so that information regarding station or marker numbers, ditches, creeks, low areas, any unusual change in apparent soil makeup, or any other pertinent information can be passed from the man with the roving half cell back to the meter reader for recording. The meter reader may at times wish to change the testing interval, depending upon how the test results are progressing. For shorter distances where the two men can always see each other suitable hand signals are adequate.

2.4.3 The meter circuit to measure the earth potential gradient is set up in accordance with one of the circuits on Figure 5. First reading is taken with the roving half cell over the structure being tested at the point where meters are set up. Successive readings are taken at predetermined intervals along the path of the buried structure with the roving half cell placed on the surface of the ground directly over the structure, the location of the structure being determined in each case first with the exploring coil locator. (The man reading the meter turns the tone source off and on as required.)

Measurement of potential readings to the roving half cell placed at these predetermined intervals directly over the structure being tested are plotted versus the distance along the cable. A change in potential toward the negative followed by a change in potential toward the positive will be indicative of a current loss area. This reasoning would appear correct provided it is further substantiated by a current loss indication from the side measurements as outlined in Paragraph 2.4.4 and analyzed in Table 1.

2.4.4 Every 50 feet, meter readings are taken with the roving half cell placed on the surface of the ground about 25 feet left of the structure being tested, then on the surface of the ground about 25 feet right of the structure being tested. Potential readings to the roving half cell are then analyzed as outlined in Table 1. Calculated results shown in Column 6 of Table 1 are plotted for each 50-foot interval for the measurements made to the roving half cell placed on each side of the structure being tested. Where the calculated results of Column 6 for the side measurements show a positive indication along with a change toward the negative and back toward the positive of the readings taken directly over the structure as outlined in Paragraph 2.4.3, a current loss area is indicated.

2.4.5 Several operations involved in obtaining the final results can be combined to save time. There could be produced directly in the field a curve, automatically plotted to scale both as to magnitude in millivolts and feet, for positions of the roving half

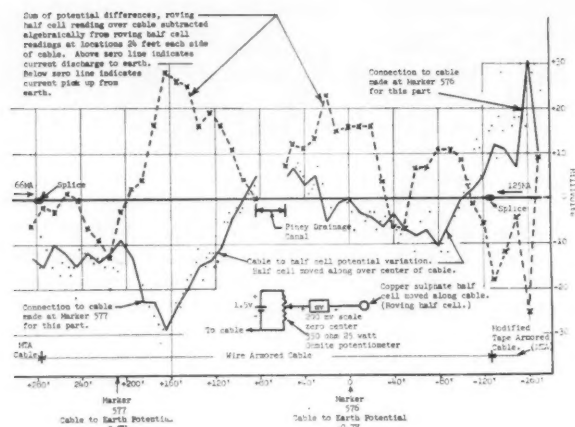


Figure 6—Earth potential gradient tests, Memphis-Little Rock "A" cable, Markers 576-577.

cell directly over the structure being tested. A horizontal scale of 1 inch = 200 feet should show sufficient detail. Location of marker numbers or stations and any other items of interest could be recorded on the graph at the time the tests were made. Potential measurements to the roving half cell placed 25 feet each side of the structure being tested could be recorded in columns provided on the graph or spotted to scale. These readings could be analyzed later as desired and a dashed curve plotted on the graph.

Such a chart would be a permanent record and would be subject to little change unless anodes are installed or the buried structure is later wrapped or replaced with one having a good coating, or another structure is buried subsequently under conditions which would cause a change in the earth gradient.

3.0 Examples and Analysis of Surface Potential Gradient Tests Along a Buried Structure

3.1 Current Loss or Hot Spot Areas

3.1.1 Figures 1 and 6 are examples of surface potential gradient tests to determine areas of current loss.

3.1.2 Figure 1 is an example of tests made between Markers 23 and 24 of the Grand Island-North Platte "A & B" gopher protected cables. This is a situation where a change in earth resistivity occurred which caused a current loss. The surface of the earth is flat and there is no apparent change in conditions at the surface which would lead one to suspect that a section of low earth resistivity existed.

3.1.3 The solid line of Figure 1 shows how the potential varied as the roving half cell was moved along over the center of the cables. Peak negative conditions are indications of current loss areas. The dashed line represents the sum of potential differences, roving half cell reading over the center of the cables subtracted algebraically from the roving half cell reading 25 feet each side of the cables. The dashed line values are obtained in the same manner as the values of Column 6 of Table 1. Positive dashed line values represent a current loss and negative

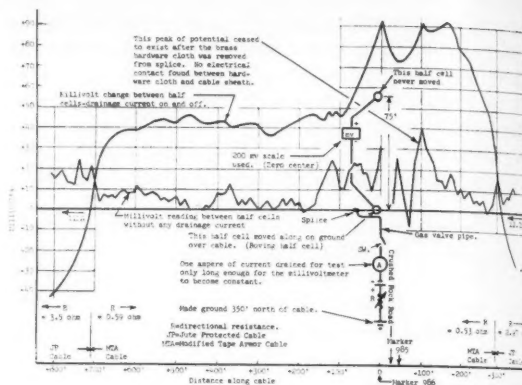


Figure 7—Earth potential gradient tests, Memphis-Little Rock "A" cable, Vicinity of Marker 986.

values a current pickup. Note that there is good correlation between current loss conditions shown by the solid and dashed lines.

3.1.4 The irregular shape of the current loss curves and the high attenuation of currents on the steel gopher tapes, particularly the latter, would indicate that mitigation by the use of magnesium anodes would require the consideration of a number of factors which are beyond the scope of this paper.

3.1.5 Figure 6 is an example of tests made where a section of wire armored cable, having galvanized wire armor, was installed across a canal as a part of a long modified tape armored cable. Test results indicate that the maximum current loss is not in the canal proper but on each side. In this case tests were made at 2-foot intervals along the surface on top of the structure being tested but only points at 10-foot intervals were joined up to form the solid curve.

It may be noticed that there may be as much as ten millivolts difference between individual readings at the adjacent 2-foot intervals, but in general a definite pattern is formed which permits an analysis to be made of the current pickup and loss areas. The curves indicate an irregular pattern in the current discharge to earth from the wire armored section with greatest discharge to earth occurring near Marker 576 + 160 feet, about 90 feet from the actual canal crossing.

3.1.6 Galvanized wire armor presents very little attenuation to the flow of anode drainage currents. In the case of Figure 6 magnesium anodes installed at the splices at each end of the wire armored cable to drain sufficient current to reduce current flow on the cable to zero would give adequate protection. Each anode installation must be adjusted for zero current flow on the cable without the anode at the other end connected. Then both anode installations are connected. An anode installation at one end only could be made to give adequate protection but it would be necessary to make an earth potential gradient survey to determine that the wire armored cable was picking up current throughout its length.

3.1.7 For long sections of wire armored cable under certain conditions it may be found that the maximum current flow on the cable does not occur at the junction with the wire armored cable. Some sections of considerable length of wire armored cable also may be picking up current. An analysis of the earth potential gradient test, however, will indicate what conditions exist and will be a guide in determining the best location for magnesium anodes.

3.2 Change in Insulation Resistance of the Covering on a Buried Structure

3.2.1 Figure 7 shows the results of tests made in a situation where a 1000-foot section of modified tape armored cable was installed in an otherwise continuous section of jute protected cable. The modified tape armored cable has steel tape over the lead sheath followed by a covering of asphalt impregnated jute. The jute covered cable is lead sheath covered with one layer of asphalt impregnated paper over the lead followed by a layer of asphalt impregnated jute. Tests were initiated to determine if the steel-lead combination was setting up a corrosion cell.

3.2.2 Measurements of current flow on the cable revealed 12.2 milliamperes entering the modified tape armored section and 11 milliamperes leaving the section. Directional resistance tests showed the resistance looking into the modified tape armored cable-to-earth was about one-sixth of that looking into the jute covered cable. This appeared unreasonable at first, but was later substantiated by similar tests made at other locations where the same combinations of cables existed. The cable was plowed in and it was at first thought that the low resistance might have been caused by damage in the plowing operations and that such damage might be determined by surface potential measurements. The higher resistance to earth looking into the jute covered cable is due to the layer of asphalt impregnated paper under the layer of jute which the modified tape armored cable does not have.

3.2.3 Arrangements were made to make surface potential measurements and in order to secure additional information arrangements were also made to drain current intermittently from the cable. The circuit arrangements are shown in Figure 7.

3.2.4 Potential measurements to the roving half cell over the cable appeared to reveal the junction of the two different kinds of cable at Marker 986 + 715 feet but not the other junction. Presence of brass hardware cloth around a splice at Marker 986-100 feet also was revealed but nothing else which warranted further investigation. The millivolt change between half cells with the drainage current on and off revealed a very definite change in the surface potential gradient as the roving half cell was moved across the junction of the two types of cable. Intermittent drainage of current along with the surface potential gradient tests, it appears, could be of value in locating sections of low earth contact resistance along a buried structure.

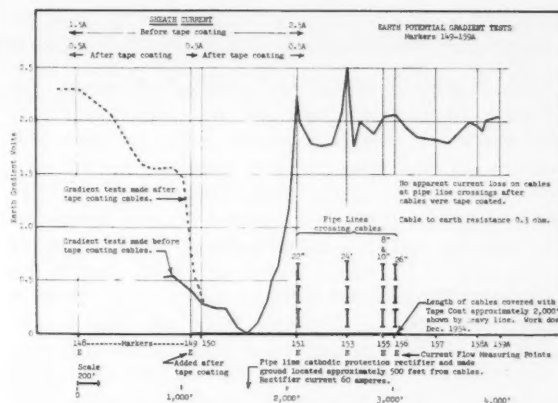


Figure 8

3.3 Interference Effects to Other Buried Structures and to Railroads

3.3.1 Where there are other buried structures in the vicinity of the proposed location for a made ground, or steam railroads equipped with dc signaling are in the vicinity, an interference problem may be involved with these other structures. Interference tests in cooperation with the owners' representatives of these structures may be required. The best way to avoid an interference problem is to obtain coordination by adequate separation. This may not be practicable in all cases because of erratic variations in the earth resistivity making few favorable made-ground locations available.

Cases have been known where made grounds located two miles away have caused trouble on railroads equipped with dc signalling. A good rule would be to keep the made ground at least one-half mile away from all structures and particularly from railroads equipped with dc signalling. The best time to determine whether interference will result to other structures is before the made ground is installed. These tests should be made with the cooperation of the other structure owners' representatives. If practicable, the tests should be made on a current "off and on" basis using the amount of current which it is expected to drain from the structure to be protected. A smaller current can be used, however, and the results calculated on a volts per ampere change basis.

3.3.2 It is probable that there always will be some interference current set up in other buried structures and railroads in the vicinity of a made ground discharging current into the earth. Whether this interfering current can be tolerated is a matter which must be decided upon by the representatives in charge of the plant being interfered with. One of the many factors involved in this consideration is knowledge of the magnitude of the interfering effect. This can only be determined by joint tests.

It will be found most convenient to express the interfering effect on the structure-to-earth potential in terms of volts per ampere change. (This does not apply to tests with railroads. See Paragraph 3.3.4.) The volts per ampere figure thus obtained can be

multiplied by the amount of current to be drained to determine the interfering effect for that current.

3.3.3 Figure 8 shows the results which can be obtained when joint tests are not made before a made ground is installed. In this case, the pipe line company notified the telephone company of the proposed construction of the made ground and the telephone company gave its consent to the proposed construction, without making joint tests. In most of the situations which come up, there might be little interference caused, but in this case there were erratic variations in the earth resistivity and a very serious situation was created on the telephone cables.

Fortunately in this case the cables were very shallow and had to be lowered in connection with other requirements so that the cost of applying remedial measures was limited to the cost of tapecoating the cables. The voltage gradient along the surface of the earth was measured using Circuit A of Figure 5. In this case, had a test drainage current of one ampere been drained from the pipe lines to a test made-ground at the ground bed location on an "on and off" basis, a voltage gradient change of about 37 millivolts per ampere would have been measured between Marker 151 at the 22-inch pipe line crossing and a point about 470 feet left of that point toward Marker 150. This would have been sufficient warning that

the made ground would be too close to the cables.

3.3.4 The telephone cables of Figure 8 could have been a railroad. The rail-to-earth resistance might be of the order of 3 to 5 ohms depending upon the road-bed ballast and weather conditions. The current on the rails would probably be about $\frac{1}{10}$ that shown for the telephone cables before tapecoating. The blocks on a railroad signal system may be one or more miles long. If the made ground were located close to the center of the block system there would probably be no effect on the railroad signals with the drainage current turned on and off.

If, however, one rail broke in the area between Markers 150 to 151 the railroad signals might operate when the drainage current was turned off and on. With the drainage current on steady, a false signal would develop in the signalling system. The location of the ground bed opposite the end of a block section where there are insulating joints in both rails would probably disturb the proper operation of the railroad signal system as long as the drainage current was turned on. Tests to determine whether any interference will be caused to a railroad signal system should be made delivering the expected drainage current to a temporary made ground at the proposed made ground location and under the supervision of a railroad signalman.

*Any discussions of this article not published above
will appear in the December, 1956 issue.*

Corrosion Control Practices for Pipe-Type Cables On the Detroit Edison System*

By W. A. SINCLAIR

THE DETROIT Edison Company installed its first commercial high-pressure pipe-type cable line in 1941. Today it has more than 60 circuit miles of this type of cable in operation. The problem of corrosion protection of the steel pipe containing the cables is similar to that of other buried pipes such as oil, gas and water lines. In obtaining such protection coatings are always used.

Somastic

The pipe is usually protected against external corrosion by a 1/2-inch thick coating of somastic. This coating consists of asphalt, asbestos fiber, sand and a mineral filler. The hot mastic is extruded on cleaned and primed pipe at the factory coating yard. A protective coating of whitewash is then applied over the mastic. The coating is then tested by means of a wire brush and spark coil at about 20,000 volts. One out of ten coated pipe lengths is tested at the factory before the pipe is shipped to the storage yard. All lengths are then tested at the yard and again just before being lowered into the trench. The apparatus used for holiday somastic testing is shown in Figure 1. Any "holidays" found are repaired and the coating retested.

The coated lengths of steel pipe are welded together and somastic applied over the welds to form a continuous coated pipe between manholes which are spaced at intervals of approximately 2700 feet. After a section of pipe between manholes has been installed, covered with clean sand or earth and wetted down, the resistance of the coating is determined by means of a 500-volt megger. To be acceptable the resistance of the coating should be not less than ten megohms per square foot of pipe area.

Ground Surface Survey

If trouble is found to exist in a section, an interrupted direct current is applied between the pipe and ground. A ground surface survey is then made using the circuit shown in Figure 2. The potential difference from a motor generator is applied intermittently between the section of coated pipe and a suitable low-resistance ground. The holidays are located by means of a vacuum-tube voltmeter which is connected between a driven ground remote from and at right angles to the pipe and a copper-copper sulfate cane. The cane is moved in short steps directly over the line. If no changes occur in the deflection of the voltmeter, caused by the interrupter, the coating is considered to be intact. When the cane is close to a coating fault, such as may result from the pipe being

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Abstract

A description is given of the procedure followed in protecting the pipe of buried pipe-type cables. The first step in protecting such pipes was to see that a 1/2-inch thick coating of somastic was applied. After the pipes had been coated and installed, a 500 volt megger was used to determine whether or not the required 10 megohms per square foot of pipe surface resistance had been attained. When irregularities were detected in a section, an interrupted direct current was applied between the ground and pipe and a ground survey was made.

A discussion is given of factors involved in the field application of somastic to pipe welds. It was found that cracking could be minimized by keeping the temperature in the mechanical mixer between 300 and 350 F.

A corrosion problem was created when several hundred gallons of cleaning fluid were lost in the ground adjacent to a manhole in the cable line area. It was decided this solvent could be kept out by treating the concrete walls of the manhole with a Thiokol Latex solution. In addition a Thiokol base material was used as a coating for the somastic-coated pipe in the saturated area. When the pipe was inspected six years later it was found there had been no disintegration of the covering. 5.4.5

exposed to the earth through a crack in a field mold, the peak ground potential is observed. Experience has shown that this method permits the test engineer to locate faults in the coating very accurately.

Upon completion of the pipe sections between manholes the three single conductor cables are installed and spliced. A steel sleeve is placed over the cable splice and welded to the pipes. This sleeve is then coated with somastic so that the pipe will not become grounded if the manhole becomes flooded.

While the pipe is being installed in the ground provisions are made for measurement of current flow along the pipe. This is accomplished by utilizing a section of the pipe adjacent to each manhole as a calibrated shunt. The lengths of these shunts are 50 feet for 7-inch outside diameter pipe and 80 feet for 8 5/8-inch pipe which have resistance of 0.612×10^{-3} and 0.715×10^{-3} ohms respectively.

Insulated leads are attached to the pipe and termi-

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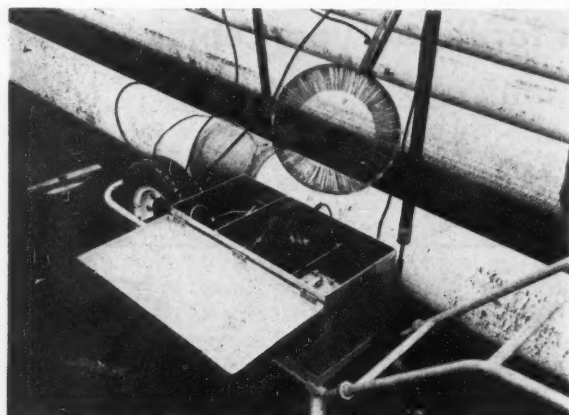


Figure 1—Holiday somastic testing apparatus—138 kv line.

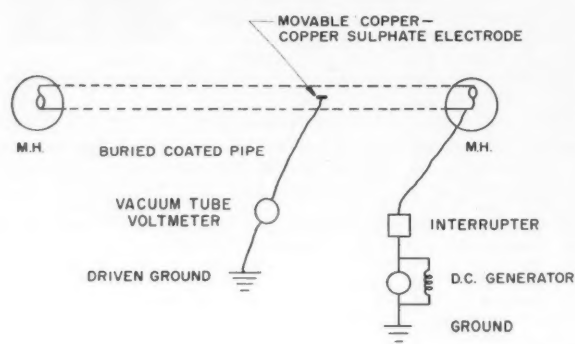


Figure 2—Circuit for ground surface survey to locate faults in coating on buried pipe.

nate in the manhole chimney. When the construction work has been completed the shunts, including the leads, are calibrated in the following manner. With the permanent grounds disconnected from the pipe at both ends, one phase conductor is connected to the pipe at one end and a constant seven ampere current circulated from the other end over the conductor and pipe circuit. Millivolt drops at each manhole caused by this current are then measured. The readings are then used to determine the resistance, the average shunt drop, and the correction factor for each shunt.

After the line is in service the condition of the somastic coating is checked when line shutdowns are possible. With the permanent grounds disconnected at both ends direct current voltage is applied between the pipe and ground. The leakage current is then held constant and the flow of current along the pipe is determined by measuring the millivolt drop over the shunts at each manhole. If the resistance of the somastic is uniform, the leakage current to ground is uniformly distributed, and the millivolt drops measured at each manhole decrease uniformly from a maximum at the sending end to zero at the far end of the line. A concentrated fault between two manholes would cause an abnormal difference between the drops obtained at the manholes on either side of the fault. Results of tests showing these effects are shown in Figure 3.

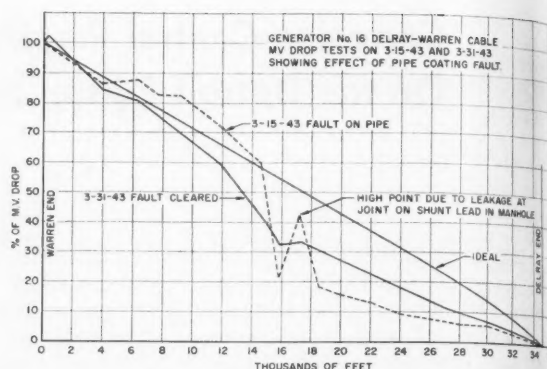


Figure 3—Effect of pipe coating fault.



Figure 4—Mechanical mixer used to melt somastic and asphalt.

Pipe Welds

The field application of somastic over the pipe welds must be done with care if the resulting coating is to be equal to that extruded onto the pipe at the factory. F. M. Hull reported in an AIEE paper¹ that it was necessary in 1949 to excavate and make repairs to the somastic covering over 50 of the 1200 welds installed.

After the joints had been buried for a short time, cracks appeared in the mold-applied covering, sometimes circumferentially over the weld and sometimes longitudinally along the bottom. When the newly completed joints were left uncovered for several days and tested, no faults would appear. After the back-filling was completed, tests would again indicate trouble.

After many experiments the cracks were eliminated by putting a recording thermometer on the mechanical mixer and giving the crew a spring scale for accurately weighing the component parts to be used in batch mixing. The mechanical mixer is shown in Figure 4.

The temperature in the mixer should be held between 300 and 350 F. During any delay of 30 minutes or more the burners should be shut off. If the temperature reaches 375 F, the batch should be thrown away. The mix should be carefully made up of 10 percent asphalt and 90 percent somastic chips by weight. The success of the control obtained is shown by the resistances measured between man-



Figure 5—View showing copper riser pipes being covered with somastic in trench.

holes on a line installed in 1950. These results are shown in Table 1. The only excavation, made at a joint 200 feet from Manhole 13405, was due to the fact that the somastic crew had missed that joint entirely. The method of covering copper riser pipes with somastic is shown in Figure 5.

Supplementary Coatings

Occasionally pipe lines are required to pass through areas in which the ground is saturated with liquids that are detrimental to somastic. In areas where the ground may contain petroleum products from refineries it is the company's practice to pour a two-inch concrete envelope around the somastic covered pipe. This type of additional protection was used on some lines constructed last year but the installations are too new to make possible a report on the permanence of the somastic under such conditions. This type of construction is shown in Figure 6.

During the excavation for a manhole on a line which was installed in 1948, a liquid having a flash point of 105 F (equivalent to naphtha) was found to be flowing out of the ground. Investigation showed that a cleaning establishment, located adjacent to this manhole, had recently lost several hundred gallons of cleaning fluid. Combustible-gas indicator tests were then made in ground test holes bored approximately four feet in depth at various locations along the line. They indicated that inflammable liquid was contained in the ground for a distance of 10 feet west of the manhole and for a distance of 25 feet east of the manhole.

The problem of protecting the cable line through this area was two-fold. First it was necessary either to protect the somastic from the action of the solvent



Figure 6—View showing a two-inch concrete envelope being poured around one of the two pipes in trench.

TABLE 1—Somastic Resistance

From Manhole	To Manhole	Length Feet	Required Resistance Ohms ¹	Obtained Resistance Ohms
13391	13392	1551	2830	20,000
13392	13393	1713	2570	10,000
13393	13394	2216	1990	70,000
13394	13395	2431	1810	60,000
13395	13396	2120	2080	30,000
13396	13397	1991	2201	45,000
13397	13398	1641	2680	17,500
13398	13399	1825	2410	Not Measured
13399	13400	2250	1955	20,000
13400	13401	2112	2080	9,500
13401	13402	1420	3100	70,000
13402	13403	2044	2150	12,000
13403	13404	2121	2070	20,000
13404	13405	2114	2080	5,000
13405	13406	2125	2070	22,500
13406	13407	2486	1770	10,000
13407	13408	2201	1980	20,000
13408	13409	2138	2040	25,000
13409	13410	2170	2010	25,000
13410	13411	2229	1970	55,000
13411	13412	2047	2140	5,000

¹ Required resistance 10 megohms per square foot of pipe surface.

or else replace the somastic with a material which would protect the pipe from corrosion and at the same time be itself unaffected by the solvent. Secondly, it was necessary to prevent seepage of the solvent into the manhole which would produce a fire hazard.

It was finally decided that the concrete walls should be treated with a Thiokol Latex solution. A Thiokol base material was chosen also as a coating for the somastic-coated pipe, through the saturated area. Both of these materials are highly resistant to solvent action by the type of inflammable liquid encountered.

Two coats of the Thiokol Latex of thinned-paint

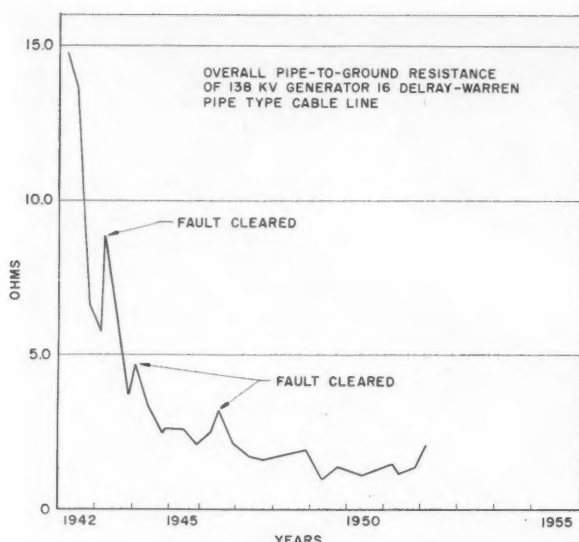


Figure 7—Overall pipe-to-ground resistance of 138 kv generator 16 Delray-Warren pipe type cable line.

consistency were brush-applied to the concrete walls of the manhole. Although one coat would have given the protection sought, the second coat was applied as an insurance that all pores of the concrete were sealed with the Thiokol mixture. Consideration was given at the time to sealing the floor of the manhole as well, but inasmuch as the combustible-gas indicator tests gave no indication that the liquid had penetrated the ground to a depth where seepage through the manhole floor might occur, it was decided that sealing of the floor might not be necessary. If, however, seepage should develop in the future through the manhole floor, steps would be taken to correct the condition. The reasoning there was that the floor could be adequately sealed either by the application of Thiokol Latex to the concrete followed by the application of a thin, additional coating of concrete to protect the sealer from foot abrasion or, by merely covering the present floor with an approximately 1/4-inch thick layer of the Thiokol material used to protect the somastic.

Because of the highly viscous nature of the Thiokol material used to protect the somastic, it was necessary that the material be mechanically formed and applied by hand to the somastic-coated pipe. By means of a clothes-wringer type of steel rolls, strips of the compound, approximately 1/4-inch in thickness, were formed and wrapped by hand on the pipe over the somastic. For the best forming of the material, it was necessary that the wringer rolls be kept wet with water during operation. The compound strips were allowed to dry before application to the pipe.

By overlapping the joints and firmly pressing each strip to the adjoining one, it was possible to obtain, in effect, a continuous coating of the material throughout the length of the pipe treated. As a margin of safety the pipe was coated, in both directions from the manhole, a minimum of five feet be-

yond the point where the combustible gas indicator revealed no further trace of the inflammable liquid. In order that the compound could be held firmly to the somastic-coated pipe until the compound developed adherence, a layer of heavy fabric was wound tightly around the coated pipe immediately following the application of each strip of the compound.

In 1954 a portion of the somastic covered pipe with the additional Thiokol covering was inspected. It was found at that time that no disintegration of the covering had taken place in the six years that it had been buried.

Over-all Pipe Resistance to Ground vs. Time

After a line is placed in service the condition of the covering is checked whenever line shutdowns are possible. A fairly good record has been obtained on the first pipe-type cable line that was installed in 1941. At the time this line was installed no provisions were made for checking the condition of the somastic before the pipe was buried in the ground. The result is that three of the 29 manhole sections had a very much lower resistance to ground than the balance of the line. The resistance of these three adjacent sections is approximately 20,000 ohms per square foot of pipe area. Numerous tests have been made and no major faults have been located in these three sections. It was found that uniform leakage was occurring and probably was caused by conducting material in the somastic. This was brought to the attention of the somastic people and the quality of the product was found to be better on later installations.

On the remainder of this line, three major faults were located and repaired as indicated in Figure 7. It will be noted that the resistance decreased rather rapidly at first and then tended to level off. Clearing the three major faults raised the resistance of the line temporarily.

Grounding

In order to provide an electrical path for line-to-ground fault currents, the pipe was solidly grounded by means of four parallel 1/0 rubber insulated cables to the station ground mass at each end of the line. A bolted lug connection was utilized to permit ungrounding of the pipe, at times when the line was de-energized, to permit periodic measurement of the overall coating resistance and to locate faults in the coating.

It is necessary on a line of this type to have small copper tubes for gas feeding connected to the pipe. These tubes were grounded along their routes. If electrically connected to the pipe they would have prevented resistance to ground measurements. Therefore hollow porcelain bushings were connected in these tubes close to the pipe to provide insulation to ground.

Reference

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The Effects of Contamination by Vanadium and Sodium Compounds On the Air-Corrosion of Stainless Steel*

By G. W. CUNNINGHAM and ANTON deS. BRASUNAS

Introduction

THE UNUSUALLY severe high-temperature corrosion of heat-resistant alloys which occurs under conditions where certain low melting constituents are present at the metal surface has received considerable attention in the past 10 years. Efforts to cope with this problem have not, thus far, been too successful.

Low melting constituents may originate either from the oxidation of certain constituents of the alloy itself, or from external sources in the environment.

The solution of this problem would permit, among other things, the use of inexpensive low grade residual fuel oils for the operation of present-day gas turbines, thus providing a cheap source of power. Furthermore, ships that rely on fuel oil for propulsion are experiencing unexpected corrosion problems when they use fuel oils bearing trace amounts of vanadium. As little as 50 parts per million of vanadium may be sufficient to create a very serious corrosion problem. The fact that oil obtained in many parts of the world contains vanadium as an impurity¹ presents a problem to naval and cargo vessels that refuel at various ports in the world.

The facts uncovered in this investigation suggest strongly that under oxidizing conditions, certain mixtures of sodium and vanadium compounds have very great affinities for oxygen. They thereby allow oxygen-rich substances to contact metal surfaces, resulting in unusually rapid corrosion of the metal under such conditions.

Although some attempts were made to study the effectiveness of additives in reducing accelerated corrosion, it was felt that a better understanding of the mechanism of attack might lead to a solution of the problem more effectively than the empirical approach. This report summarizes the authors' attempts and findings. It is hoped this information may lead to a better concept of the problem and an eventual solution to it.

The corrosion problem, simply stated, appears to be the destruction, by certain contaminants, of the corrosion resistant layer which normally forms on heat resistant alloy surfaces. The destructive reaction is merely the formation of a pervious complex or mixed oxide by reaction of atmospheric oxygen and contaminants, such as vanadium pentoxide, with the metal surface. The reaction product, being no longer an effective barrier to diffusion, permits the corrosion reaction to proceed at an unimpeded rate; hence accelerated corrosion occurs at rates which may be considered to be catastrophic.

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Abstract

The acceleration of high temperature corrosive attack on heat-resistance alloys caused by the presence of vanadium compounds is well established. The progressive addition of sodium sulfate to the vanadium contaminant indicates that the most corrosive mixture is approximately 20 percent sodium sulfate—80 percent vanadium pentoxide. The survey of the melting temperatures of various vanadium pentoxide—sodium sulfate mixtures shows no direct correlation to corrosive behavior. There appears to be a strong indication, however, that unusually high oxygen solubility in the molten contaminant containing 20 percent sodium sulfate may be responsible for its unusually high corrosiveness. This makes it possible to postulate a more satisfactory theory of the mechanism of corrosive attack which need not involve a solid phase at the reaction interface.

Additions of calcium oxide, strontium oxide, and carbon were particularly effective in reducing the intensity of attack. The effectiveness of carbon is restricted to short time intervals during which it became oxidized.

3.5.9

Avenues of Approach

Theoretically, the solution to the general problem of accelerated corrosion may be approached by any of the following means:

1. Remove the source of difficulty (i.e., vanadium and similar substances).

- a. eliminate such alloying elements as molybdenum and vanadium from heat resistant alloys, and
 - b. Remove traces of vanadium, sulfur, etc., from the fuel oil, and/or other environmental sources.
2. Add a substance that will deactivate the troublesome component; i.e., calcium oxide may be injected as a slurry into the fuel oil to combine with the V_2O_5 to form a relatively stable and inactive compound, as $Ca(VO_3)_2$.
 3. Alter conditions so that V_2O_5 may be reduced to a high melting (and therefore less active) compound (such as V_2O_3); add carbon or alter the fuel-air ratio to maintain reducing conditions at the metal surface.
 4. Develop an alloy which will inherently be resistant to this corrosive environment.
 5. Develop a coating on the metal surface which will protect the underlying metal from attack. It must resist the "slagging" action of V_2O_5 or other corrosion-accelerating contaminants.
 6. Operate at lower temperatures so that the low-melting phase is not molten. (This is not a practical approach to gas turbine problems, because high operating temperatures must be used to obtain satisfactory operation and efficiency.)

This investigation was aimed at gathering facts which would lead to a better understanding of the mechanism of this form of corrosion, with particular attention to the behavior of contaminants rich in sodium sulfate and vanadium pentoxide. There have been references^{2,3,4,5} in the technical literature indicating that the severity of corrosive attack is increased when sodium sulfate is present in certain proportions. Thus, if the reason for this increased attack were known, appropriate steps could more effectively be taken to cope with this problem.

Review of Previous Investigations

The unique characteristic of accelerated corrosion, that the corrosion rate is not reduced by the presence of a scale layer but is linear (or perhaps even more rapid than linear) has been established experimentally by Brasunas and Grant⁶ for certain vanadium-bearing heat resistant alloys. This fact alone indicates that the presence of the oxide layer actually accelerates the corrosion rate. It has been demonstrated by these investigators that certain components of the oxide layer, known to accelerate corrosion, become enriched at the metal-oxide interface and catalyze the reaction between oxygen and metal atoms.

Accelerated corrosion may be encountered when (1) Metals are alloyed with alloying elements whose oxides are low-melting, such as molybdenum, vanadium, lead, bismuth, rhenium, etc., or (2) The surfaces of "truly heat-resistant" alloys are contaminated by contact with low-melting oxides or other salts such as halides, sulfides, etc. The investigations of Brasunas and Grant,⁶ Leslie and Fontana,⁷ Kessler and Hansen,⁸ and Brenner⁹ illustrate the acceleration of corrosion by the first method (internal

contamination). Numerous investigators have studied the acceleration of corrosion by the second method (external contamination).^{1-5,10-20}

At least two attempts have been made to explain corrosion acceleration. One school of thought⁷ is that certain oxides dissociate to form a sub-oxide and nascent oxygen, the latter being exceptionally reactive and hence causing rapid corrosion. The second school of thought^{6,11,12} is that a molten oxide at the metal-oxide interface destroys the corrosion resistant layer and leads to rapid corrosion. The later explanation which is discussed in greater detail elsewhere in this paper appears to be currently more acceptable.

Leslie and Fontana⁷ observed that accelerated corrosion of an alloy containing 16 percent Cr, 25 percent Ni, 6 percent Mo, and balance iron was erratic. That is to say stagnant air atmospheres favored severe attack, whereas flowing air atmospheres favored shallow corrosion.

A subsequent study of this problem by Brasunas^{6,11} demonstrated that atmospheric circulation was important only when the corrosion-accelerating contaminant was highly volatile, as with MoO_3 , but was ineffective when the contaminant was only slightly volatile, as V_2O_5 . Brasunas prepared a molybdenum-bearing alloy and a comparable vanadium-bearing alloy to demonstrate this behavior; the normal oxidation of the alloy itself supplied the accelerating contaminant to the scale. His observation that an increase in the temperature of the corroding specimen was above that of the surrounding furnace led to an explanation of one of the several primary factors which results in the unusual accelerating corrosion rate.⁶ A series of tests were described by Brasunas and Grant¹¹ which indicated that many low-melting metal oxides are capable of accelerating the air-corrosion rate of normally-heat resistant alloys by mere contact with their surfaces. The contaminants studied included MoO_3 , WO_3 , V_2O_5 , PbO , Bi_2O_3 , KF , and some mixtures of these substances.

Synthetic Oil Ash

Evans¹⁴ compared the effects of a synthetic oil ash on various types of heat resistant steels. He suggested that the best solution to the accelerated corrosion problem might lie in the addition of compounds to the oil to form a chemically inert ash. He also investigated the effect of various mixtures of sodium sulfate and vanadium pentoxide, and concluded from tests run at 1350 F that the attack by $Na_2SO_4-V_2O_5$ mixtures was approximately constant between 10 and 80 percent V_2O_5 . Ash mixtures richer than 80 percent in vanadium were found to be more corrosive and those richer than 90 percent in sodium sulfate were less corrosive.

Sykes and Shirley¹⁵ studied the increase in the scaling rate caused by sulfur and oil ash constituents when the fuel to air ratio was varied. It is surprising to note that they did not detect any effect on the scaling rate caused by either sulfur or Na_2SO_4 individually, regardless of the fuel-air ratio which varied from 2:1 to 6:1.

Buckland, Gardiner, and Sanders¹⁶ gathered a great

deal of data on the corrosion of many types of metals caused by various synthetic oil ashes as well as tests involving the actual contact of fuel-oil combustion gases with the metal. They were interested in a practical solution to the problem. After they found that most heat resistant alloys were susceptible to rapid deterioration under these conditions, they then tried to alleviate this corrosion problem by the use of various additives placed in the oil stream.

In 1953, Fitzer and Schwab¹⁷ stated that the presence of vanadium in the fuel oil caused rapid corrosion and suggested that the best solution lay in the removal of vanadium from the oil.

Sodium Sulfate

Monkman and Grant² substantiated the original theory proposed by Brasunas¹³ and in addition did some work on the role of sodium sulfate in oil ash corrosion. They attributed the effect of sodium sulfate on the corrosion rate¹ to the change of the melting point of the ash and² to the dilution of vanadium pentoxide by sodium sulfate.

Widell and Juhasz¹⁸ ran thermal arrest curves to determine the "softening points" of several $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures. These softening points were reported to be practically constant at 150 to 200 degrees F lower than the melting point of vanadium pentoxide (1240 F). It should be noted that the heating and cooling rates used were very rapid (35 F to 70 F per minute at the arrests) and hysteresis effects could be pronounced.

Buckland¹⁹ in 1954 in a supplement to his original paper¹⁶ pointed out a practical solution in which sodium sulfate was removed from the oil and magnesium oxide was added to reduce the corrosive effects of vanadium pentoxide.

Frederick and Eden⁴ have recently published an article in which they state that the rate of scaling increases with increasing temperature and increasing time, and that the addition of sodium sulfate markedly increases the rate of attack. The maximum attack occurred with mixtures of 10 percent Na_2SO_4 and 90 percent V_2O_5 . A great deal of additional work also was done with various additives such as MgO , Al_2O_3 , and ZnO .

McFarlane and Stephenson⁵ indicated that they had investigated the increased corrosion caused by $\text{Na}_2\text{O-V}_2\text{O}_5$ mixtures and had found a maximum attack with mixtures of 80 mol percent V_2O_5 . They suggested that it would be possible for $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures to decompose to highly corrosive vanadyl vanadates.

Simons, Browning and Liebhafsky²⁰ recently investigated the effect of sodium sulfate on the corrosion rate of stainless steel. It was found that in the absence of reducing conditions, there is no appreciable increase in the corrosion rate. However, if an alloy is subjected to a cycling reducing and oxidizing condition above 800 C, rapid corrosion may occur.

Harris, Child, and Kerr²¹ published an article which gave the results of a study to determine what effect the composition of an alloy had on the scaling rate due to vanadium pentoxide contamination. They con-

clude that a "reasonable" resistance is provided by alloys which contain the following materials in the indicated proportions: chromium, > 16 weight percent; iron, < 30 weight percent; and vanadium, < 2 weight percent.

Liquidus Curves

Lucas, Weddle, and Preece²² published "liquidus curves" for binary phase diagrams of ten different oxides with V_2O_5 . Oxides which were mixed with V_2O_5 were Al_2O_3 , BeO , CaO , Co_3O_4 , Cr_2O_3 , MgO , NiO , CuO , Fe_2O_3 , and ZnO . Several of these systems have been reported more accurately previously^{2,13,23} and the accuracy of this work is questionable because of the experimental method used.

The authors prepared intimate mixtures of oxide mixtures by ball-milling. Next a water paste was made of the mixture which was then preheated at 550 C before being heated to the softening temperature. The specimens were in the form similar to Segar cones and the temperature was determined by an adjacent chromel-alumel thermocouple. The points where sagging started were recorded as was the temperature at the point where the cone touched the silica hearth. The heating rates used were not given. These investigators also presented the results of the attack on pure chromium by V_2O_5 . It was shown that the nature of the attack was such that rapid oxidation was continuous and if the supply of V_2O_5 were periodically renewed the metal would completely oxidize in a relatively short time. It was also indicated that attack would continue even when the total amount of V_2O_5 in the scale was less than 5 percent. The exact location of the V_2O_5 in the scale was not stated. It was implied, however, that the V_2O_5 was uniformly distributed (an unlikely condition).

Corrosion Tests

Corrosion tests were made in conventional resistance-wound muffle furnaces which were controlled to give various test temperatures accurate to within 10 degrees F. In all cases, except where noted otherwise, tests were performed in an air atmosphere containing 4 percent water vapor by volume. Air was preheated to test temperature before allowing it to contact the metal specimens.

Alloy steel bars were machined into cup-shaped specimens having a V-notch as shown in Figure 1. This notch acted as a reference point for corrosion depth measurements which were obtained using the depth measuring device described previously by Brasunas.¹ Its simple principle of operation permits direct measurement of the depth of attack. However, prior to the determination of the depth of corrosion, it was necessary to descale the test specimens as will be described later.

The machined metal test specimens were carefully degreased in benzene and acetone prior to corrosion testing. They were then placed into cavities in a ceramic test block (porous silica) as shown in Figure 1. Measured quantities of a corrosion-accelerating

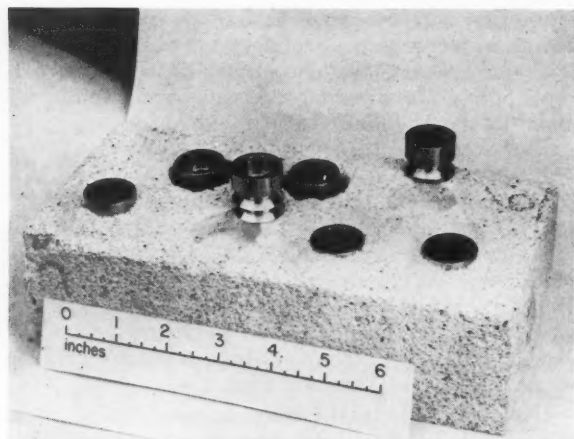


Figure 1—Method of packing specimens for corrosion tests. Photograph shows specimens before and after packing.

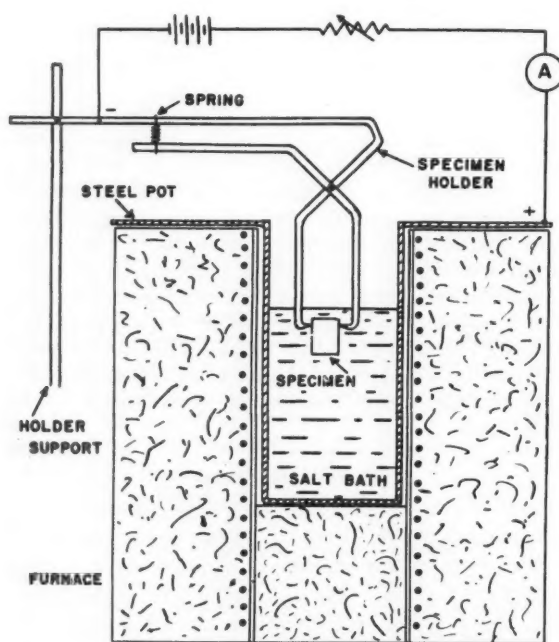


Figure 2—Electrolytic descaling apparatus.

TABLE 1—Chemical Analyses of Alloys Tested

Identification	Composition ¹ —Weight Percent					
	C	Cr	Ni	Si	Mn	Other
JA-1	.058	18.48	10.48	0.37	1.16	.....
JA-4	.052	17.38	10.83	0.35	1.75	2.30 percent Mo
JA-5	.056	18.15	9.18	0.40	1.13	.....
JA-7	.21	15.80	35.08	0.39	1.62	.....
JA-8	.066	24.80	19.80	0.60	1.87	.....
JF-2	.125	12.2	0.0	0.32	1.05	.....
JF-4	.068	17.54	0.0	0.33	0.36	.....
JF-6	.12	11.89	0.0	0.30	0.48	.....

¹ Balance iron.

TABLE 2—Composition by Weight of No. 1 Ash

V ₂ O ₅	Na ₂ SO ₄	SiO ₂	Al ₂ O ₃	PbO	FeO	NiO	Cr ₂ O ₃
74.38%	10.18	5.15	2.01	2.16	2.07	2.04	2.01

contaminant, such as a synthetic fuel oil ash, were placed into the cup and its effects on metal corrosion were noted. Powdered ceramic particles were used to fill the remainder of this cavity so as to prevent the creep of the contaminant to the notched area. Such creep could invalidate subsequent depth measurements, and precautionary measures were necessary for that reason.

Descaling

A major portion of the heavy scale layer could easily be removed by hand, but the removal of the more adherent inner layers required a special technique. Complete descaling was accomplished by using an electrolytic method; the specimen was made the cathode, submerged in a molten salt bath (composed of 60 percent sodium carbonate and 40 percent sodium hydroxide) for two minutes, and finally quenched into water. The salt bath was maintained at approximately 1000 F. A sketch of the apparatus used is shown in Figure 2.

A current density of 200-300 amperes per square foot was found to give satisfactory results. The scale removal was accomplished by subjecting the specimen to a thermal shock, as well as the reduction of the oxide to a fine non-adherent metal powder. Occasionally, the descaling technique was repeated if the scale layer were found to resist descaling.

Alloys Tested

Although a wide range of alloys were studied with respect to their ability to withstand the increased corrosive action caused by the presence of fuel oil ash contaminants, none were found to be satisfactorily resistant. The analyses of the heat resistant alloys tested are given in Table 1. Alloy JA-5 was selected for making comprehensive tests to determine the effects of time, amount of ash, temperature, and the effectiveness of various additives.

Effects of Amount of Contaminant

In view of the fact that the presence of contamination is deleterious to corrosion resistance it obviously is important to determine the maximum amount that would cause preceptible increases in the corrosion rate. One should expect this quantity to be dependent upon the nature of the ash composition; for this reason Ash No. 1, the highest in vanadium content, was used. Its composition (weight percent) is given in Table 2.

Alloy JA-5 (18 percent Cr-8 percent Ni alloy) was selected for testing at 1550 F (720 C). Amounts of ash as low as 0.0050 gram were used. There is a definite correlation between the intensity of attack and amount of ash introduced. This may be observed in Figure 3 which shows the specimens after a 16-hour exposure. This length of time was found to be sufficiently long to show the increased corrosion rates caused by the presence of contaminants.

To evaluate the corrosiveness of various contaminants and the effectiveness of various corrosion-inhibiting additives, 0.25 gram of ash was used as a



Figure 3—Effect of corrosion acceleration caused by increasing amounts of No. 1 Ash contaminant on Alloy JA-4 (1550 F—16 hours). Note that the rate of attack increases when ash contaminant is present, especially in amounts greater than 0.054 gram.

standard quantity. Variations in amount of contaminant were occasionally used and are so indicated whenever varied.

Effect of Time on Rate of Attack

In making quantitative studies of the progress of corrosion, importance of testing time must be considered. This is especially true if the rate is not linear, as is frequently the case. Technical people frequently extrapolate short time corrosion test data to predict long time behavior or vice versa. Such extrapolation could be very misleading and should be done with proper caution.

It seemed desirable, therefore, to establish the relationship between corrosion and time for these tests. A Type 316 stainless steel, Alloy JA-4, was selected for test and contaminated with 0.25 gram of No. 1 Ash. It was then exposed to a moist air atmosphere at 1550 F for varying lengths of time ranging from one hour to two hundred hours. The appearance of the corroded specimens is shown in Figures 4 and 5. After descaling, using the technique described previously, the depth of corrosion was measured using the depth-measuring device. The results of these measurements are shown graphically in Figure 6.

The initiation of accelerated attack is time-dependent and may be clearly illustrated in the side view of the test specimens shown in Figure 5. Tiny specks of deeper attack may be seen to nucleate on the sides of the one-hour test specimen. These become the zones of intense attack which may be clearly seen on the five-hour test specimen.

Contamination by $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ Mixture

Other investigators have indicated that the presence of Na_2SO_4 in V_2O_5 may alter the intensity of corrosive attack and therefore should receive some attention. Appropriate binary mixtures of these two substances were prepared from chemical reagents and placed in the cup-shaped specimens for corrosion testing at a series of temperatures.

The test data, summarized in Table 3, were plotted and are shown in Figure 7. The most intense corrosion appeared to be restricted to the region of 20 percent Na_2SO_4 and 80 percent V_2O_5 . Excluding this region of severe corrosion, one may conclude that the intensity of attack is a function of the V_2O_5 content; the Na_2SO_4 , except in the above critical region,



Figure 4—Effect of time on the extent of air-corrosion of a Type 316 stainless steel specimen at 1550 F.

acts as a diluent. The appearance of this series of test specimens is shown in Figure 8. An uncontaminated specimen is shown in the center for comparison.

Contamination by $\text{Na}_2\text{O-V}_2\text{O}_5$ Mixtures

At elevated temperatures, particularly in the presence of V_2O_5 , sodium sulfate tends to decompose²⁴ to Na_2O and SO_3 . It seemed reasonable, therefore, to expect similar corrosion effects from both types of contaminants, especially in low nickel alloys which are relatively resistant to sulfur-bearing environments.

Alloy JA-5 was exposed, therefore, to several mixtures of $\text{V}_2\text{O}_5\text{-Na}_2\text{SO}_4$ and analogous mixtures of $\text{V}_2\text{O}_5\text{-Na}_2\text{O}$ at 1300 F and 1650 F for 50 hours. The corrosion data are summarized in Table 4.

Effect of Additives to Ash

The reduction in fuel oil ash corrosion of heat resistant alloys caused by certain additions to the ash has been established by previous investigators.^{3,14,16,17} It was suggested also that NiO , CaO , MgO , and C were desirable substances because of the possibility of forming compounds of high melting point through

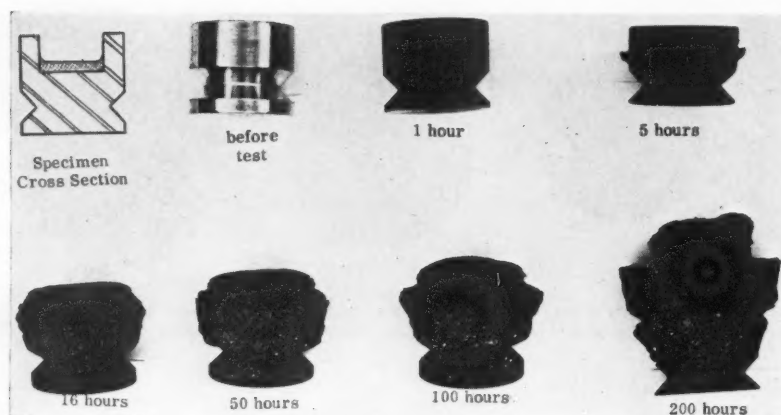


Figure 5—Effect of time on the progress of accelerated air-corrosion caused by contamination with 0.25 gram No. 1 Ash on Alloy JA-4 at 1550 F.

TABLE 3—Depth of Metal Converted to Oxide for Alloy JA-5 in a Moist Air Atmosphere at Several Temperatures in the Presence of $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ Contamination

ASH MIXTURE		DEPTH OF ATTACK—Inch					
% Na_2SO_4	% V_2O_5	1130 F	1170 F	1290 F	1390 F	1650 F	1800 F
0	100	.000	.000	.000	.011	.021(.036)	.074(.030)
5	95	.000	.000	.001	.012	.020(.034)	.042(.017)
10	90	.000	.001	.000	.012	.020(.034)	.040(.016)
15							
20	80	.001	.001	.004	.025	.038(.064)	.040(.016)
26				.002	.018		.035(.014)
					.012		.050(.020)
30	70	.001				.016(.027)	.042(.017)
32	68	.001	.002	.001	.003	.007(.011)	.025(.010)
40	60						
50	50	.001	.001	.002	.003	.003(.005)	.022(.009)
60	40					.002(.003)	
70	30					.001(.002)	.027(.011)
80	20	.001	.001	.001	.003?	.001(.001)	
90	10					.001(.001)	.030(.012)
100	0					.001(.001)	.017(.007)
Test Duration		80 hr	60 hr	60 hr	60 hr	60 hr ¹ (100 hr)	60 hr ¹ (24 hr)

() Actual test data.

¹ Calculated from test data, assuming linear relationship.

interaction. Experiments confirmed this, and furthermore showed that BaO and SrO also were effective inhibitors.

The effectiveness of some of these additives may be illustrated by Figure 9 which shows the appearance of several test specimens after 100-hour exposures at 1550 F. The apparent ineffectiveness of the carbon addition was verified in subsequent tests with larger quantities of carbon. Figure 10 shows that even when 0.335 gram of graphite is added to 0.25 gram of No. 1 Ash, no reduction of attack is effected in a 100-hour exposure.

Carbon additions of 0.12 gram and 0.025 gram were made to the No. 1 Ash, and their effectiveness was studied at various time intervals. Figure 11 illustrates the appearance of test specimens after one, five, sixteen, fifty, and one hundred hour exposures. Beneficial effects are noticeable only for the shorter time intervals.

Carbon additions also were made to Na_2SO_4 contaminant to obtain a reducing condition. There have been reports that increased attack may be expected under such conditions. Two alloys, JA-5 and JA-7, were tested at 1650 F for 100 hours under the following conditions:

1. Uncontaminated.
2. Contaminated with 0.25 gram Na_2SO_4 .
3. Contaminated with 0.25 gram Na_2SO_4 plus 0.3 gram carbon.

Test results indicated that the depth of metal corroded at the top and bottom of the cup-shaped specimens was as given in Table 5.

The importance of degreasing the specimen prior to testing was investigated. Corrosion test specimens were handled by numerous persons to ensure a "greasy finger" condition. These samples were then contaminated further with sodium sulfate and exposed to air at 1550 F for a 100-hour period. The intensity of attack was light (0.001 inch) both for degreased and undegreased specimens. These tests were repeated using alloys JA-4, JA-5, JA-7, and JA-8. No difference in corrosion behavior was noted.

Effectiveness of Phosphate Coatings

A number of test specimens were coated with a ceramic slurry which was received from Dr. Franz Drexler.⁽¹⁾ These slurries are rich in phosphates and use isopropyl alcohol as vehicle. Metal specimens were coated, after careful degreasing, and subsequently dried and fired. The latter treatment caused

a metal-phosphate layer to develop which formed an adherent corrosion resistant layer. Some difficulties were experienced, however, in reproducing an adherent coating after the firing operation. When this was obtained, however, a good protective surface resulted.

Quantitative data were not dependable because of the erratic adherence experienced. Several grades of heat resistant alloys were coated; these included Alloys JF-6, JA-5, JA-7, and JA-8. Tests were conducted at 1550 F for a 100-hour period using No. 1 Ash as contaminant. Whenever adherence of the phosphate coating was good, excellent protection was evident.

A measurement of the intensity of attack was made where adherence was good. It was found to be less than one mil. This certainly represents excellent protection for a very corrosive condition. It was observed also that the tendency for the ash to creep out of the cup-shaped specimens was arrested when a small amount of the phosphate-base slurry was placed around the lip of the cup.

$\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ Diagram

Previous investigators^{6,12,13} have pointed out the

(1) Associated with the Badische Anilin- and Soda-Fabrik.

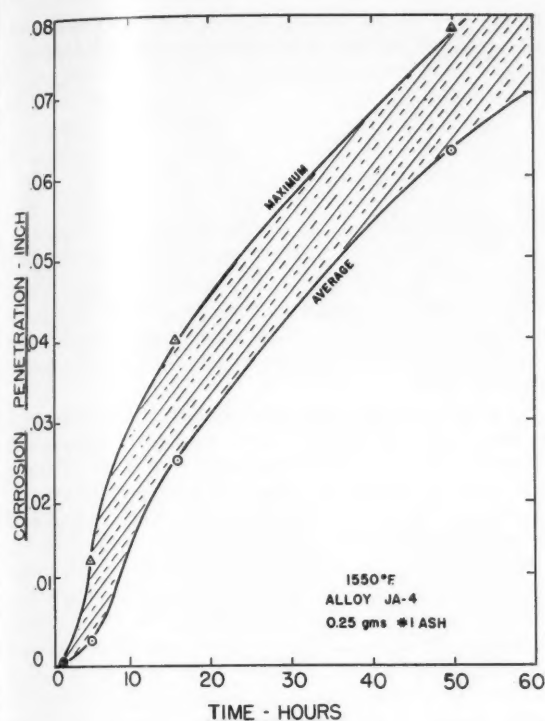


Figure 6—Effect of time on the corrosion rate. First there is an increase, then a gradual decrease in rate.

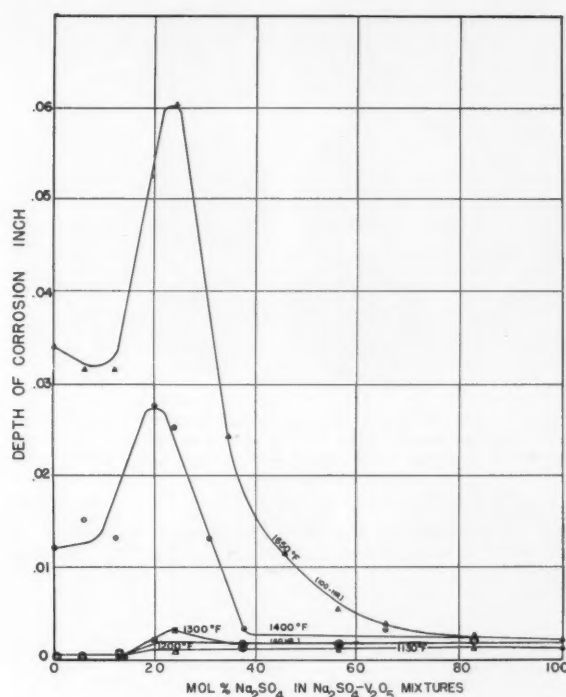


Figure 7—Effect of composition of $\text{V}_2\text{O}_5\text{-Na}_2\text{SO}_4$ mixture on the air-corrosion of Alloy JA-5.

necessity of a molten oxide film at the metal-oxide interface for the promotion of accelerated corrosion. Therefore, an important aspect of corrosion by $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures would involve a determination of the melting ranges of these mixtures.

Finely ground mixtures of vanadium pentoxide and sodium sulfate were prepared for melting point determinations and were placed in platinum crucibles. Upon being heated into the molten range, a platinum, platinum-10 percent rhodium thermocouple was inserted for time-temperature measurements during cooling and heating cycles. The thermal arrests, indicating the start and completion of solidification (and fusion), were noted in the usual manner and used to prepare the thermal arrest diagram shown in Figure 12.

The diagram is drawn from thermal arrest data, obtained by heating and cooling various mixtures at rates varying from 3 C to 10 C per minute. The apparatus used for this work is shown in Figure 13. A compound (comparable to $\text{Na}_2\text{SO}_4 \cdot 6\text{V}_2\text{O}_5$) was located by the use of X-ray diffraction data obtained from the various fused mixtures (see Table 6). These X-ray diffraction data are summarized in Figure 14. The presence of a compound at this point was further verified by diagram construction.

The validity of the diagram is not affected by the oxygen absorption, which is discussed in the following section, because this process is reversible and absorption occurs in the melting range of the mixtures. However, there may be some error due to

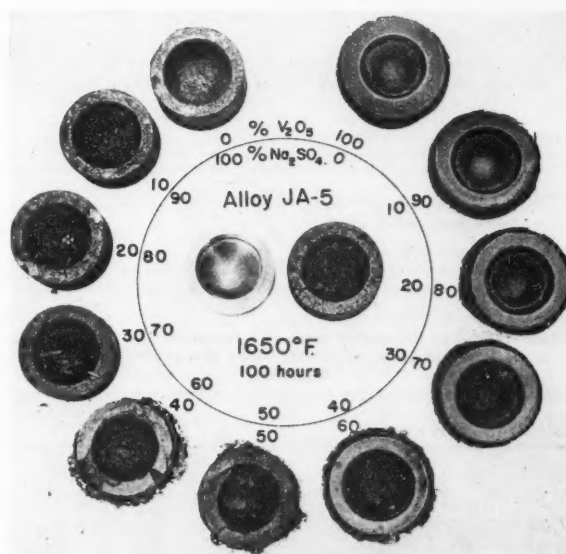


Figure 8—Effect of composition of contaminant on the air-corrosion of Type 304 stainless steel at 1650 F.

partial decomposition of sodium sulfate. Nevertheless, there is reason to believe, as explained later in the section on decomposition of sodium sulfate, that the slight dissociation which was caused by heating the mixtures in the range studied did not cause any appreciable change in the freezing temperatures.

The thermal-arrest data obtained during solidification may be slightly in error, particularly if the

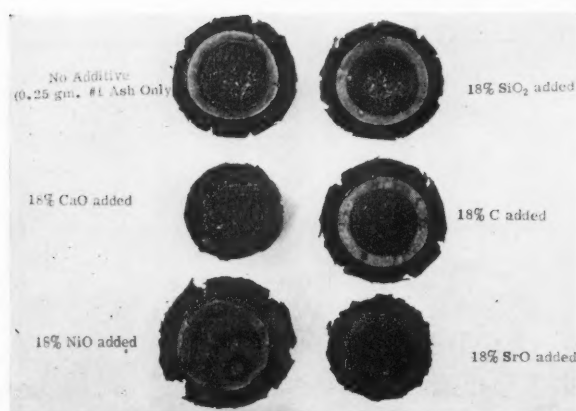


Figure 9—Effect of varying additions to 0.25 gram No. 1 Ash contaminant on air-corrosion of Alloy JA-4 at 1550 F in 100 hours. Note that the extent of attack is lowered by calcium oxide and strontium oxide additions.

TABLE 4—Corrosion of Alloy JA-5 in a Stagnant Air Atmosphere at Several Temperatures in the Presence of Sodium and Vanadium Contaminants

Na ₂ SO ₄ Mixtures				Na ₂ O Mixtures			
Ash Mixture		Depth of Attack—Inch		Ash Mixture		Depth of Attack—Inch	
Mol % Na ₂ SO ₄	Mol % V ₂ O ₅	1300 F	1650 F	Mol % Na ₂ O	Mol % V ₂ O ₅	1300 F	1650 F
0	100	.001	.041	0	100	.001	.041
13	87	.001	.082	13	87	.002	.094
20	80	.002	.071	20	80	.002	.063
33	67	.001	.024	33	67	.001	.005
50	50	.002	.001	50	50	.001	.001

Note: Test Duration 50 hours; 0.5 gram contaminant used for each specimen.

TABLE 5—Effect of Carbon on the Depth (Inch) of Air-Corrosion of Alloys JA-5 and JA-7 in Presence of Sodium Sulfate

Testing Condition	Alloy JA-5 (Type 304)		Alloy JA-7 (Type 330)	
	Top	Bottom	Top	Bottom
Uncontaminated	.000	.001	.000	.001
Contaminated with Na ₂ SO ₄	.002	.002	.000	.014
Contaminated with Na ₂ SO ₄ and C (open)	.001	.004	.000	.013
Contaminated with Na ₂ SO ₄ and C (closed)	.004	.020	....	....

TABLE 6—X-Ray Diffraction Lines of a Fused Na₂SO₄-V₂O₅ Mixture¹ as Determined on Norelco Unit Using Nickel-Filtered Copper Radiation

Relative Intensity I/I _m	Angle 2θ	d-Value Å
.22	9.5	9.30
1.0	12.5	7.08
.16	18.0	4.92
.08	18.8	4.72
.12	24.9	3.57
.28	25.9	3.44
.12	26.9	3.31
.88	29.5	3.02
.09	31.0	2.88
.16	36.1	2.49
.88	41.8	2.16
.09	46.2	1.90
.09	47.8	1.90
.25	55.3	1.65
.09	60.7	1.52
.12	62.6	1.48

¹ Composition: 16 percent Na₂SO₄—84 percent V₂O₅.

amount of material solidifying is small. In fact, some thermal arrests might even escape detection. This may be attributed to the poor thermal conductivity of these mixtures. Similarly, interruptions in heating

curves may be difficult to detect. Data obtained upon reexamining the data and repeating the solidification studies are believed, however, to be reliable. The accuracy of the eutectic temperatures is believed to be within 5 degrees C; the melting points of the pure components were found to be within 3 degrees C of the accepted values.

Oxygen Absorption by Molten Na₂SO₄-V₂O₅ Mixtures

It was observed during the thermal arrest studies that certain molten salt mixtures rejected a gas upon solidification. This reaction seemed to be reversible inasmuch as it could be repeated with every heating-cooling cycle.

It was believed that this phenomenon could be a factor in the accelerated corrosion phenomenon and therefore the gas absorbing power of these mixtures was determined. The vycor apparatus, shown previously in Figure 13, was modified slightly and used in making a quantitative study of gas solubility.

Measured quantities of the various mixtures were weighed and placed into the platinum crucible which was then sealed into the glass system. The system was initially evacuated and one atmosphere of oxygen was introduced; the glass system was then sealed.

As the temperature was slowly raised, the pressure was observed to increase. This increase could be attributed to two factors: (1) The Charles relationship, and (2) The partial dissociation of the salts. In some instances, a pressure decrease was observed; this was attributed to oxygen absorption by the molten mixtures.

For more than a hundred years it has been known that vanadium pentoxide-alkali salt mixtures evolve oxygen upon being cooled from the liquid to the solid state. According to Mellor,²⁴ W. Prantl stated that the "spitting" which occurs when the molten alkali acid vanadates solidify is due to the reversible change of the acid vanadate to the vanadylvanadate when the reaction given below proceeds to the right.



Verification of this equation was not attempted in this study. The chemical analysis of vanadium compounds is very difficult to make, and the suppression of the oxygen evolution needed for obtaining the alkali acid vanadate would present additional problems.

Absorbed Oxygen

The important factor considered here is that oxygen may be readily absorbed by these molten mixtures and that this absorbed oxygen apparently is readily given up by the mixtures during solidification. This absorption is not confined to the Na₂O-V₂O₅ system, but has been reported to occur in other systems such as Li₂O-V₂O₅ and K₂O-V₂O₅.^{13, 25} In this investigation the Na₂SO₄-V₂O₅ and Na₂O-V₂O₅ systems were studied. An important consideration of this phenomenon, however, is that it has not been shown to exist in any system which does not contain alkali metal constituents. It has been reported, in fact, that no such absorption can occur except in the presence of an alkali metal.²⁴

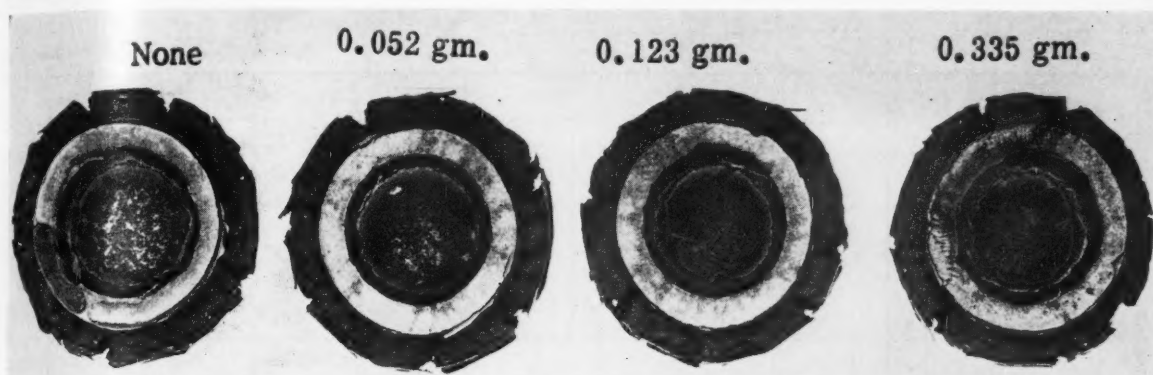


Figure 10—Effect of increasing the carbon content in ash contaminant on air-corrosion of Alloy JA-4 at 1550 F (100 hours). Carbon additions are ineffective in suppressing attack in 100-hour exposure tests.

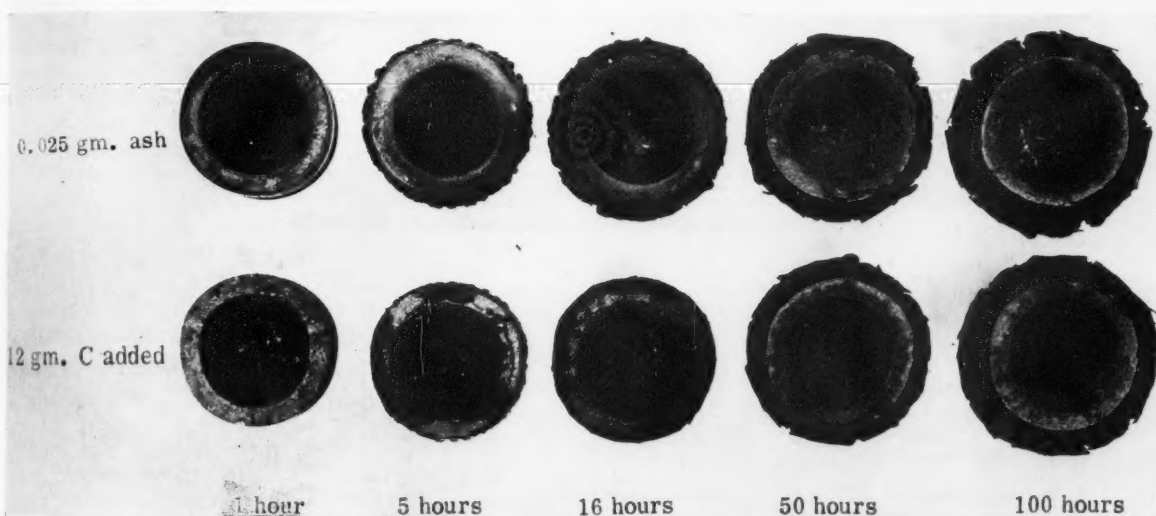


Figure 11—Appearance of Alloy JA-4 specimens with and without 33 percent carbon additions at several time intervals after air-corrosion at 1550 F.

As $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures and $\text{Na}_2\text{O-V}_2\text{O}_5$ mixtures solidify, the oxygen previously absorbed in the molten state is rapidly evolved. The solidifying mass appears to bubble up to a height in proportion to the amount of oxygen released. Photographic illustrations of this behavior are shown in Figures 15 and 16. Note that the amount of oxygen evolved varies with the composition.

If one were to consider a closed system containing oxygen and a mixture of $\text{Na}_2\text{O-V}_2\text{O}_5$, the pressure ordinarily would be expected to change upon heating up to the melting range at a constant rate in accordance with the ideal gas law ($P = \frac{nRT}{V}$). Above the melting range of the mixture, however, there might be rapid decrease of pressure resulting from the absorption of oxygen which would gradually slow down as the liquid approached "saturation" at the higher temperature.

Another factor which must be considered in $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5\text{-O}_2$ systems is the dissociation of Na_2SO_4 to $\text{Na}_2\text{O} + \text{SO}_3$. It has been reported²⁶ that dissociation occurs much more readily in the presence of V_2O_5 than any of the other oxides studied. If this dissocia-

tion were observed in a closed system, one would expect the pressure/temperature ratio to increase discontinuously at temperatures slightly above the melting range of the mixture, where measurable dissociation begins. It would be expected to increase at a rapid rate with further temperature increase.²⁶ Consequently, when heating $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures, one might expect the resulting temperature-pressure curve to be modified by two phenomena: oxygen absorption and the dissociation of Na_2SO_4 . This type of behavior is actually shown in the experimental curves of Figure 17.

It might be pointed out that the curve for a $\text{Na}_2\text{O-V}_2\text{O}_5$ mixture shows only the effect of oxygen absorption, while the curve of the $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixture shows the combined effects of oxygen absorption and SO_3 evolution caused by partial sodium sulfate decomposition. It is interesting to note that both vanadium pentoxide and sodium sulfate alone are essentially stable at temperatures well above the temperature range of these experiments. Unusual effects are observed, however, when these substances are mixed.

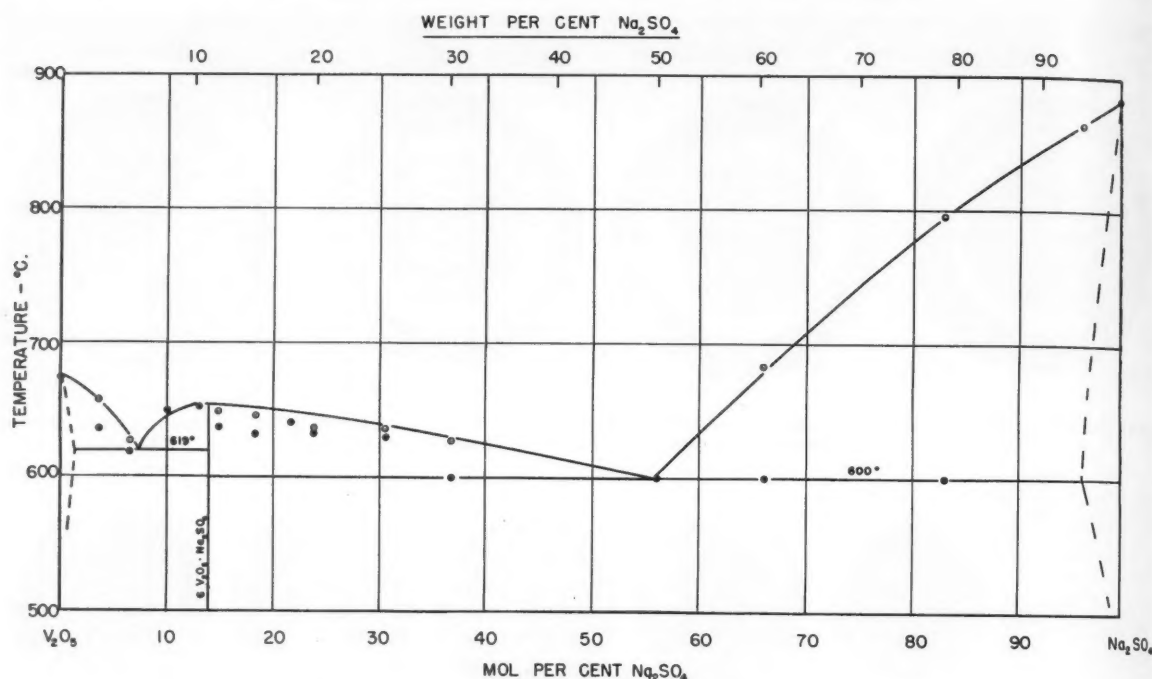


Figure 12—Sodium sulfate-vanadium pentoxide thermal arrest diagram.

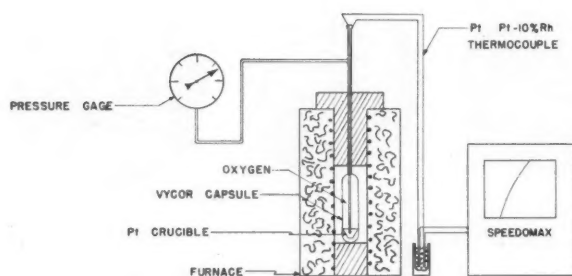


Figure 13—Thermal analysis apparatus.

Inasmuch as this investigation was concerned with the $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ system, a few comments will be made to explain in detail the $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ curve shown in Figure 18. As the mixture of V_2O_5 powder and Na_2SO_4 powder is heated (Curve 1), the initial slope is comparable to that of air heated in the apparatus with no sample present. At 674 C (the melting point of V_2O_5) a gas is liberated, presumably because of reaction with Na_2SO_4 , to form sodium vanadate or some molten complex.

As the mixture continues to be heated, there is no further increase in pressure until a temperature of approximately 770 C is reached. This flat portion of the curve corresponds to an absorption of oxygen by the liquid. Above 800 C the pressure begins to rise rapidly indicating that the dissociation of Na_2SO_4 far exceeds the oxygen absorption by the mixture.

Upon cooling (Curve 2), the absorbed oxygen apparently is retained in the liquid until the melting range is reached, at which time there is an abrupt increase in pressure due to rapid rejection of oxygen. Upon further cooling, the normal slope of a pressure-

temperature curve is evident. If the fused mixture is then reheated (Curve 3), the cooling curve is reproduced up to the melting range, then the liquid begins to absorb oxygen, resulting in a decrease in pressure.

Dissociation again occurs upon further heating to 900 C, resulting in an increased pressure. If the system is kept sealed, these heating and cooling curves (Curves 2 and 3) may be reproduced by repeated heating and cooling cycles. It will be noted that these reversible curves are at higher pressures than the initial mixture of powdered reagents. This higher pressure may be attributed to the presence in the system of some SO_3 gas which was released by the initial heating and which did not go back into solution upon cooling.

Weight Percent Sodium Sulfate

A series of reversible heating and cooling curves has been obtained for mixtures of vanadium pentoxide and sodium sulfate containing the following weight percent sodium sulfate: 0.0, 5.0, 10.0, 16.3, 20.0, 26.0, 34.0, 50.0. The data for these mixtures are reproduced in Figures 19 and 20. In order to give a clear picture, only heating curves are shown, inasmuch as cooling curves show similar pressure-temperature relationships. Furthermore, heating curves may provide more reliable data because of the fact that all heating runs were started at room temperature, whereas the upper temperature to which the various specimens were heated was varied. For that reason a direct comparison of the oxygen absorption capacity and the dissociation which had occurred for these mixtures could not be made from cooling studies. The reason for not heating to a constant high

temperature was the pressure limitations on the glass and vycor apparatus used.

Figure 19 shows the temperatures at which the discontinuity in slope of the curves occur for various mixtures. On the same graph it may be noted that rapid dissociation of sodium sulfate appears to occur at lower temperatures in the vanadium-rich mixtures. In order to make graphic the data shown in Figure 20, the curves of Figure 19 were superimposed at the incipient melting points of the mixtures and the minimum gas pressure exhibited by the soft or molten mixture was recorded. This arrangement allows a qualitative comparison of the extent of oxygen absorbed by the various mixtures studied.

An examination of Figure 17 indicates that there is little or no absorption of oxygen by pure molten vanadium pentoxide and there appears to be no measurable dissociation. However, the curves in Figure 18 show that there is a definite absorption of oxygen by $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures. Furthermore, there is a progressive increase in the oxygen absorbing capacity, as is apparent in Figure 20, as Na_2SO_4 is increased from 0 to 16.32 weight percent. In the range 16.32 to 50 weight percent, the absorbing capacity for oxygen decreases slowly, and mixtures containing more than 50 percent Na_2SO_4 have very little oxygen absorbing capacity. The 50 percent Na_2SO_4 mixture in Figure 20 shows this behavior.

Dissociation of Na_2SO_4 by V_2O_5

At temperatures above 800 C the increased dissociation of Na_2SO_4 in molten V_2O_5 is quite noticeable. In some cases one may even observe white acid fumes of SO_3 rising from the molten mass. Tseft and Salibaev²⁶ gave a report on the increased dissociation of Na_2SO_4 caused by adding various oxides to Na_2SO_4 . Their findings are given in Table 7.

In the authors' study of pressure-temperature relationships, the dissociation of Na_2SO_4 by heating $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures was established by the presence of SO_3 as a dissociation product. This was verified by bubbling the evolved gases through a barium hydroxide solution and precipitating barium sulfate. In all samples tested, the mixtures of high vanadium content showed measurable dissociation above 800 C. It should be pointed out, on the other hand, that the gas evolved upon solidification did not precipitate visible amounts of BaSO_4 .

Pressure-temperature curves are plotted in Figure 21 for a 26 percent Na_2SO_4 -74 percent V_2O_5 mixture after two stages of dissociation. Curve 2 is identical to Curve 3 in Figure 18 and represents the equilibrium heating curve of the original fused mixture in a closed system. Curve 1 was obtained after the system was opened to an air atmosphere, heated to 900 C, and held for two hours. During this time, evolved SO_3 above the surface of the specimen was driven off by natural convection currents. The specimen was then cooled and the system sealed in the presence of one atmosphere of oxygen. Curve 1 of Figure 21 was then obtained upon heating. A close examination of the curves shows a less sharp rise in pressure (from points B to C) due to SO_3 evolution

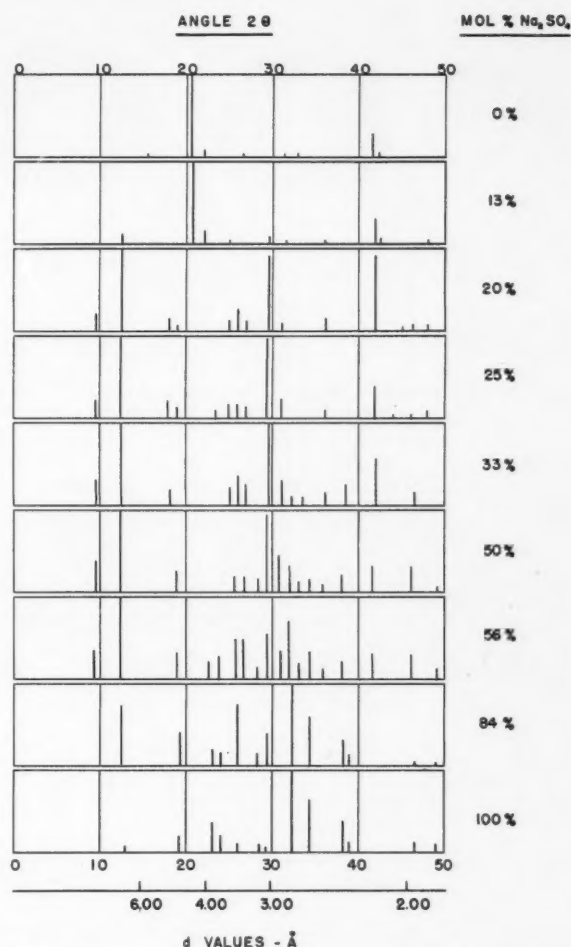


Figure 14—Sketch of X-ray diffraction patterns of fused $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures.

TABLE 7—Effect of Various Oxides on the Dissociation of Na_2SO_4

Reagents	Temperature at Which Measurable Dissociation of Na_2SO_4 Occurs—Degrees C
Na_2SO_4	1070
$\text{Na}_2\text{SO}_4 + \text{Al}_2\text{O}_3$	1045
$\text{Na}_2\text{SO}_4 + \text{Fe}_2\text{O}_3$	1045
$\text{Na}_2\text{SO}_4 + \text{SiO}_2$	1030
$\text{Na}_2\text{SO}_4 + \text{V}_2\text{O}_5$	740

after the two hour heating in open air. The absorption of oxygen was slightly more emphasized after SO_3 was permitted to escape and the melting range of the mixture was lowered approximately 10 degrees C and was increased slightly in span.

It should be pointed out that the extent of dissociation in the two hour heatings in open air far exceeds any dissociation experienced during the determination of the thermal arrest diagram. The thermal arrest specimens were held at temperature for very short periods of time only; i.e., a matter of a few minutes.

Discussion

Previous investigators⁶ have suggested a mecha-

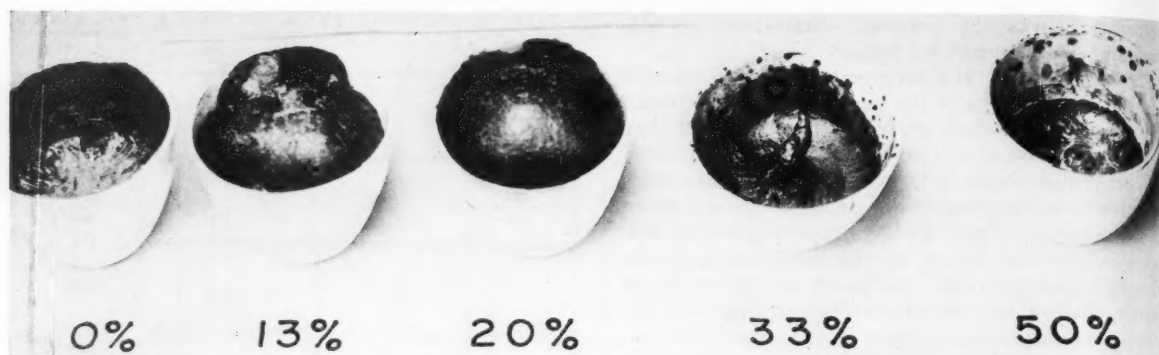


Figure 15—Photographic illustration of comparative amounts of oxygen rejected upon solidification of $\text{Na}_2\text{O}-\text{V}_2\text{O}_5$ mixture. Height of solidified mixtures is proportional to the amount of oxygen released. Figures at bottom represent mol percent Na_2O .



Figure 16—Photographic illustration of comparative amounts of oxygen rejected upon solidification of $\text{Na}_2\text{SO}_4-\text{V}_2\text{O}_5$ mixtures. Height of solidified mixtures is proportional to the amount of oxygen released. Figures at bottom represent mol percent Na_2O .

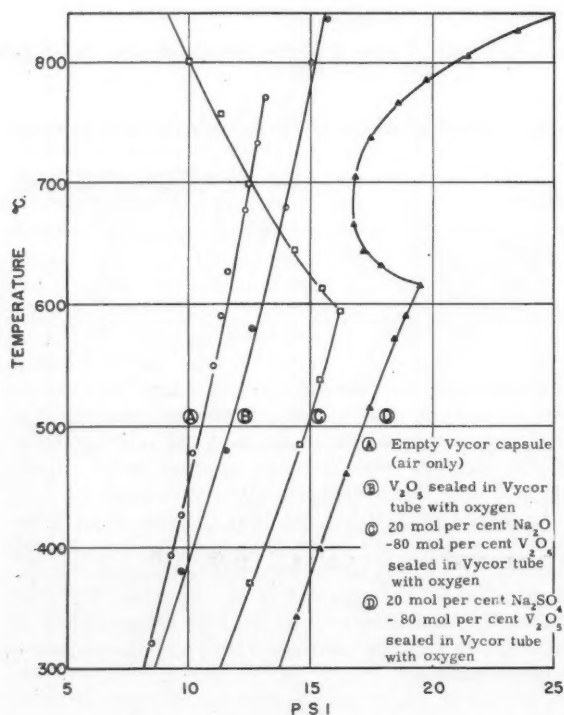


Figure 17—Typical pressure-temperature curves for various mixtures compared to a blank.

nism for metal corrosion caused by vanadium pentoxide in which the V_2O_5 forms a metal oxide and a vanadium sub oxide which is regenerated by oxygen in the atmosphere to the pentoxide. If this type of mechanism holds for $\text{V}_2\text{O}_5-\text{Na}_2\text{SO}_4$ mixtures, one would expect the Na_2SO_4 to act simply as a diluent with the corrosion rate influenced primarily by the relative amount of V_2O_5 present.

On the other hand, if the melting ranges are taken into consideration as a prime factor, one would arrive at the same conclusions proposed by Monkman and Grant.² Those authors concluded that there would be an added oxidation effect due to the higher fluidity of low melting mixtures, in which case there would be increased oxidation at those compositions where the fluidity reaches a maximum. According to the thermal arrest diagram shown in Figure 12, this point should be at approximately 5 weight percent Na_2SO_4 , and again at 45 weight percent. This does not agree with experimental data shown in Figure 7 or with previously reported data.^{2,16}

The corrosion data listed as in Table 3 and shown graphically in Figure 7 indicates that V_2O_5 alone is extremely corrosive when present on the surface of a Type 304 (Alloy JA-5) alloy, especially above 1300 F. The test data at 1270 F, which is slightly above the melting point of V_2O_5 , do not indicate a particularly high corrosion rate. However, at higher temperatures the corrosion rate increases sharply.

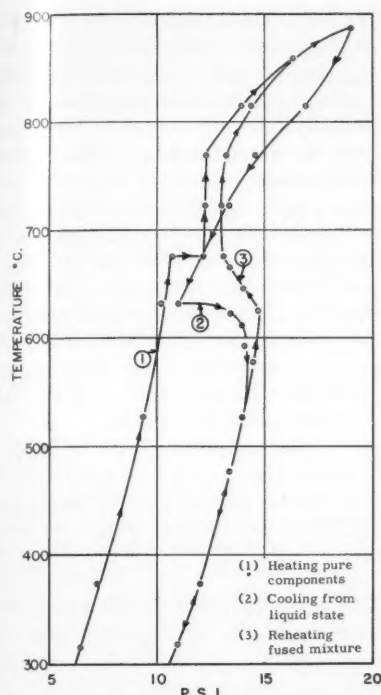


Figure 18—Pressure-temperature relationships for heating and cooling a 26 weight percent Na_2SO_4 -74 weight percent V_2O_5 mixture.

When Na_2SO_4 is progressively added to the V_2O_5 contaminant, the corrosion rate increases sharply, reaching a maximum in the region of 15 to 20 percent, and then decreases rapidly with further additions of Na_2SO_4 .

Except for the peak of corrosion intensity which exists between 10 and 30 percent Na_2SO_4 in V_2O_5 , one may be justified in saying that, up to 1650 F, pure V_2O_5 is a severe corrodent. It may be said also that the progressive addition of Na_2SO_4 gradually reduces the attack intensity to a very low figure (as though the specimen were uncontaminated) when more than 70 percent Na_2SO_4 was present.

The unusually severe attack in the 10-30 percent Na_2SO_4 , 90-70 percent V_2O_5 region must be explained. A noticeable correlation can be made, however, between corrosion data from this investigation and certain physical property data. This correlation is that the maximum corrosive attack occurs within the range 10 to 30 weight percent Na_2SO_4 in V_2O_5 , and at the same time the maximum absorption of oxygen occurs in molten mixtures of this same composition range.

If reference is made to the thermal arrest diagram shown in Figure 12 and to the corrosion data given in Figure 7, it may be stated that no increased attack occurred when the temperature of the specimen was lower than the melting point of the contained contaminant. Furthermore, no major increase in attack occurred until a reasonably fluid mixture was obtained. This occurred at temperatures approximately 100 F above the melting range.

The experimental data of the corrosion tests show

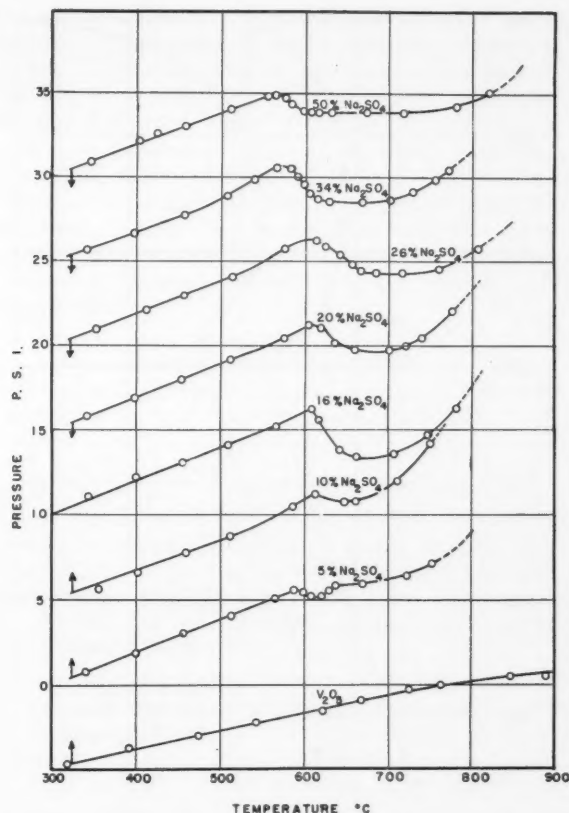


Figure 19—Pressure-temperature relationships of various Na_2SO_4 - V_2O_5 mixtures. The pressures as shown are correct only for the 16 weight percent Na_2SO_4 mixture. All other curves have been displaced to eliminate superimposition in order that their true shapes may be compared.

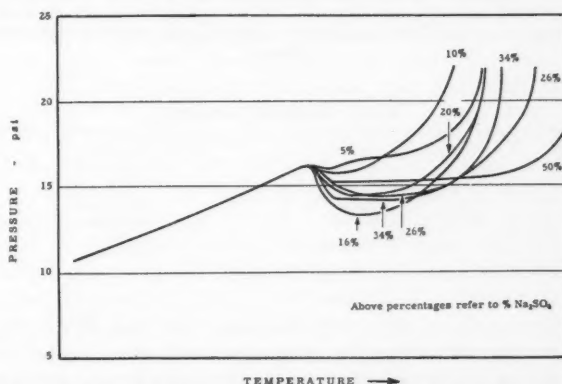


Figure 20—Pressure-temperature curves for various V_2O_5 - Na_2SO_4 mixtures superimposed at solidus to illustrate comparative pressure drops during heating at 3 degrees C per minute.

that, in agreement with other authors,^{1,4,21,22} very little contaminant need be present to cause greatly increased attack. The oxide which is formed as a result of the presence of corrosion-accelerating contaminants is very porous and apparently does not appreciably hinder the passage of oxygen to the metal-oxide interface. These factors suggest the importance of the speed at which oxygen passes through the molten oxide film. However, the presence of the

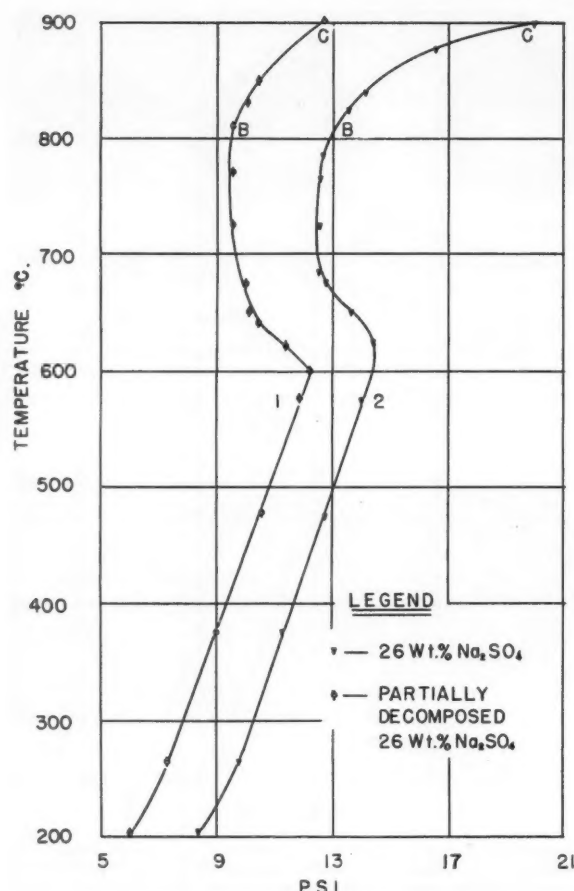


Figure 21—Dissociation effects on pressure-temperature curves. Curve 1 was produced by heating a specimen previously allowed to dissociate at 900 C for two hours. Curve 2 was produced by heating the specimen used to produce Curve 1 previous to the dissociation treatment described above.

TABLE 8—Binary Diagrams

V_2O_5 — Al_2O_3 ²² CaO ^{13,22,23} BeO ²² Co_3O_4 ²² Fe_2O_3 ^{13,22} MoO_3 ¹³ ZnO ²²	V_2O_5 — Cr_2O_3 ^{13,22} Na_2O ^{2,13,22} MgO ²² CuO ²² Na_2O ^{13,25} Li_2O ^{13,25} K_2O ^{13,25} Ti_2O_3 ^{13,25}
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film itself is also very important as was shown by Brasunas¹³ when he demonstrated that oxidation during the initial stages of corrosion was much more severe in the presence of liquid V_2O_5 than in a pure oxygen atmosphere. These corrosion tests also show a general tendency for greater corrosion by Na_2O - V_2O_5 mixtures in the vanadium-rich composition range than by Na_2SO_4 - V_2O_5 mixtures of the same mol percent.

When certain desirable additives are present in Na_2SO_4 - V_2O_5 mixtures, three effects have been noted: (1) the melting ranges of the mixtures are raised, (2) New compounds are formed, and (3) The amount of oxygen soluble in the salt is sharply decreased. The first effect has been recognized and the effects of metal oxides on the melting range of V_2O_5 -metal

oxide systems have been studied; some of these have been reported as binary diagrams (see Table 8).

The formation of new compounds is indicated by the binary diagrams referred to, although the crude liquidus temperatures of Harris, Child, and Kern²² are hardly to be considered as reliable evidence of compound-formation.

The authors have made X-ray diffraction studies of the very corrosive Na_2SO_4 - V_2O_5 mixture with and without the presence of an additive. When MgO was added, a new crystalline substance was formed; new X-ray diffraction lines appeared and were attributed to this new phase. No attempts were made to identify it, although the mixture itself corresponded to $6 MgO \cdot 4 V_2O_5 \cdot Na_2SO_4$ (i.e., 21.8 weight percent MgO or 53.5 mol percent MgO).

Although the molar ratio $4 V_2O_5 \cdot Na_2SO_4$ corresponds to the region of high oxygen solubility, the introduction of 21.8 weight percent MgO resulted in oxygen solubility decreasing almost to the vanishing point.

Effect of Quantity of Contaminant

As shown previously in Figure 3, the quantity of corrosion-accelerating contaminant is important in spite of the accepted idea that "a little goes a long way." It should be obvious that if only a trace of V_2O_5 is present on the metal surface, and if it is not replenished when partially reacted with naturally forming corrosion products, the V_2O_5 will continually be diluted until the new oxide forming at the metal-oxide interface,⁶ is eventually uncontaminated. This uncontaminated oxide therefore should form the normal non-porous layer which could then afford protection.

The time required to reach this stage, or depth of metal which must first be consumed, is primarily dependent upon the amount of ash, and the nature of the ash. It may be assumed that the other variables such as alloy being attacked, temperature, and nature of the ambient atmosphere are fixed.

Using a Type 316 alloy (JA-4), No. 1 Ash (approximately 75 percent V_2O_5), and air at 1550 F, it was found that 0.005 gram of contaminant was ineffective in accelerating attack. It was found that 0.054 gram was also ineffective, whereas 0.25 gram showed a considerable corrosive behavior, and 0.63 gram of No. 1 Ash gave very severe attack.

Thus one may conclude that under these conditions some small critical amount of ash must be present before accelerated corrosion results. In this case, the amount appears to be in the proximity of 0.1 gram No. 1 Ash.

Effect of Time

When a standard quantity of ash is used, as 0.25 gram, and the time at temperature is varied, there appears to be an incubation period before accelerated corrosion begins. The appearance of Alloy JA-4 specimens immediately after testing is shown in Figures 4 and 5. Accelerated attack has not become evident after a one-hour exposure, although close examination of the specimen shows a few areas of

"incipient accelerated attack." These areas are clearly seen in the five-hour exposure, and beyond this, the rapid attack spreads.

The curve illustrating the depth of metal attack as a function of time shows a definite accelerating stage which is characteristic of this type of attack.⁶ The deceleration which might appear to be a second stage of attack is merely the dilution effect discussed in the preceding section, which one expects when the available contaminant becomes diluted with continued corrosion. If the supply of contaminant were renewed, or if its source were the alloy itself, deceleration would not occur.

Effect of Reducing Conditions

It has been suggested that reducing conditions might be effective in retarding or eliminating accelerated attack. This idea may have originated from the well-founded concept that V_2O_5 , which has a low melting point, might be reduced to a lower oxide form which has a higher melting point. This should certainly remedy the situation.

Many reducing agents could be used, but their presence might further contaminate the area. Therefore, carbon was selected as a reducing agent and intimately mixed with No. 1 Ash in varying quantities, ranging from 0 percent to 60 percent. One hundred hour tests at 1550 F showed no improvement as a result of carbon additions; test specimens were shown previously in Figure 10.

It seems reasonable to conceive of carbon burnout in short periods of time, and therefore short time tests would appear to be more desirable. The test was repeated using 0.25 gram of No. 1 Ash and 0.12 gram of carbon; test results were compared to a carbon-free series. As expected, the long time exposures showed no difference, whereas the short time exposures may be seen in Figure 11 to show that carbon did reduce accelerated corrosion. Hence, to be a practical means of protection, carbon additions would be required at frequent intervals. This, however, does not seem feasible. The attainment of reducing conditions by control of fuel-to-air ratios is also impractical because calculations indicate that such extremely reducing conditions would be required that the fuel consumption would be ridiculously high. Furthermore, required operating temperatures would not be maintained.

When sodium sulfate alone is used as a contaminant, very little increased corrosion is observed under oxidizing conditions. It is a well-known fact that sulfur-bearing environments are most harmful under reducing conditions, particularly to nickel-rich alloys. Two alloys, JA-5 and JA-7 (Types 304 and 330 respectively), were exposed to sodium sulfate with and without carbon additions. Uncontaminated specimens were lightly corroded, whereas the sulfate-contaminated specimens were more severely attacked, especially the high-nickel alloy. When carbon was added, alloy JA-5 suffered more attack, whereas JA-7, which suffered heavy attack by Na_2SO_4 , was not attacked more severely when carbon was present.

One specimen of JA-5 was contaminated with car-

bon and Na_2SO_4 . The cup was then "capped" with platinum to maintain strongly reducing conditions within. As may be seen by the quantitative data in Table 5, very severe attack resulted (i.e., ten times the attack observed under oxidizing conditions).

In several instances Duriron specimens (high silicon cast iron) were included in tests. These were found to be resistant to accelerated attack under all conditions tested. It is unfortunate that this alloy must be used in cast form, and has such unpopular mechanical properties that it is not workable or machinable.

Summary and Conclusions

It has been demonstrated that the severe corrosion of heat resistant alloys when contaminated by V_2O_5 is aggravated by additions of Na_2SO_4 up to 30 percent, the most severe mixture being in the region of 15-20 percent Na_2SO_4 . This increased corrosion cannot be explained by reference to changes in melting points, but seems to be related to the oxygen solubility in the molten Na_2SO_4 - V_2O_5 mixtures. The mixture which is most corrosive is also the mixture which dissolves the greatest amount of oxygen when molten.

Even though a small amount of surface contamination is ordinarily required to cause accelerated corrosion, it was found that quantities less than 0.1 gram did not cause a perceptible increase in attack. Furthermore, if the contaminant were introduced initially, rather than periodically or continually, the rate of attack would be expected to decrease gradually and eventually reach normal rates. If the contaminant were supplied at frequent intervals, severe corrosion would continue.

Although Na_2SO_4 is quite stable when heated up to 1800 F, the introduction of metal oxides, particularly V_2O_5 , causes the sulfate to dissociate to Na_2O and SO_3 . Na_2O - V_2O_5 mixtures behave very similarly to the Na_2SO_4 - V_2O_5 mixtures; in fact, there seems to be a gradual decomposition of the latter, making it identical to the former.

Certain additives can be used successfully to retard accelerated corrosion. There are indications, however, that some of these materials cannot be used commercially and require the proper combination of type, temperature, time, and amount, for the condition to be treated.

As the test temperature increases, the intensity of attack increases quite sharply. At temperatures below 1300 F, however, the corrosion rates are quite low. Accelerated corrosion is rarely encountered with heat resistant alloys at such low temperatures. As far as the characteristics and conditions accompanying accelerated corrosion are concerned, one may postulate the following:

1. A molten oxide film is necessary for the promotion of accelerated corrosion. At temperatures below the melting point of the contaminant, normal corrosion is encountered.
2. If a limited quantity of low melting contamination is present and is not replenished, the corrosion rate will decrease.

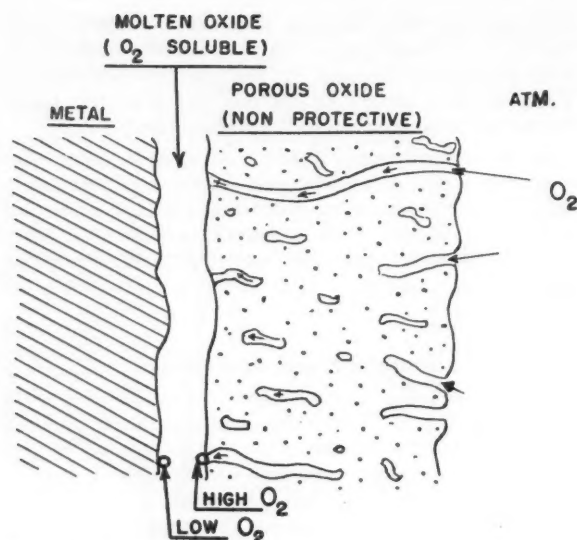


Figure 22—Proposed mechanism of corrosion accelerated by presence of low melting point constituents at metal-scale interface.

3. There is a critical amount of ash necessary to start accelerated attack. This is approximately 0.1 gram per square inch of surface area, but will vary with composition and other parameters.
4. An incubation time may be encountered, which may be the time required for the ash to react with the thin oxide film normally formed before the contaminant became active (i.e., molten and in contact with metal).
5. The oxide scale is porous as illustrated in Figure 22, which provides for free access of atmospheric oxygen to the molten oxide film at the metal-oxide interface. This interface is the zone of reaction.
6. Molten $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures exhibit high absorbing capacity for oxygen. The mixtures with the maximum absorptive power shown in Figure 23 lie in the range 16 to 20 weight percent Na_2SO_4 which is also most corrosive (see Figure 7).
7. Molten $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures will reject the absorbed oxygen to the atmosphere upon solidification, but the absorbed oxygen is available in the molten mixture for reaction with metal as indicated in the proposed mechanism described below.
8. In the vanadium-rich mixtures, the rate controlling step at constant temperature appears to be the rate at which oxygen passes through the molten film to the metal surface.
9. $\text{Na}_2\text{O-V}_2\text{O}_5$ mixtures behave similarly, but appear to be slightly more corrosive than $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures to the Type 304 (18 Cr-8 Ni) alloy.
10. $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures slowly decompose to the more corrosive $\text{Na}_2\text{O-V}_2\text{O}_5$ mixtures.
11. Carbon decreases the corrosion rate caused by vanadium-rich ashes during the early stages of exposure; its presence increases the rate of

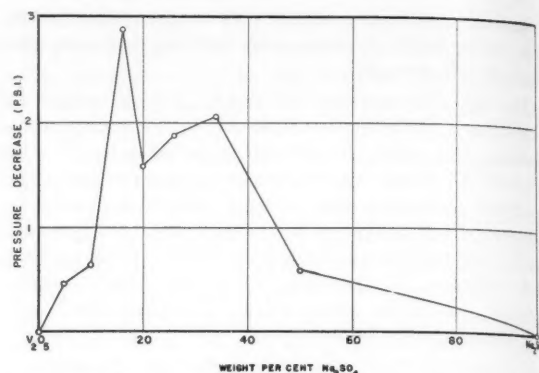
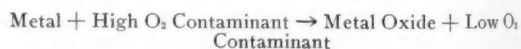


Figure 23—Decrease in pressure due to oxygen absorption above the solidus temperature for various $\text{Na}_2\text{SO}_4\text{-V}_2\text{O}_5$ mixtures. Heating rate: 3 degrees C per minute.

attack of sodium-sulfate rich ashes, especially for high nickel alloys.

12. Calcium, barium, and strontium oxides are always beneficial; magnesium oxide is frequently a beneficial addition to vanadium-rich ash. Silica additions up to 18 percent do not appear to be beneficial.
13. Duriron was the only alloy tested which resisted accelerated corrosion.
14. Phosphate coatings are beneficial to heat resistant alloys if their adherence can be assured.
15. The unusually high corrosion encountered when 80 percent $\text{V}_2\text{O}_5\text{-20 percent Na}_2\text{SO}_4$ is present as contaminant on the surface of a heat resistant alloy at temperatures above 1500 F is caused by the reaction between metal and the oxygen dissolved in the molten contaminant according to the following reaction:



Thus the molten layer appears to act primarily as an oxygen carrier and a destroyer of protective films.

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Any discussions of this article not published above
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Selection and Application of Coatings In the Pulp and Paper Industry*

By RAYMOND B. SEYMOUR*

Introduction

THE SUCCESSFUL use of plastic structures such as pipe, valves, pumps, stacks and ducts in pulp mills demonstrates that these same plastics when properly applied as coatings can be used to protect buildings and processing equipment in the pulp and paper industry.

The base products utilized for both plastic structures and coatings are similar; their principal difference is in application techniques. All plastics must be selected carefully, but in addition, coatings also must be applied properly.

Information on the selection of plastics for the general use as protective coatings has been published previously.^{1,2,3,4} Charts which may be used as guides for the proper selection of coatings materials in the chemical process industry also are available.^{5,6}

Information published previously will not be duplicated, but an attempt will be made in this paper to provide practical information on the selection and use of protective coatings in the pulp and paper industry. For the sake of brevity, this discussion will be limited to a few universally used coatings which will protect equipment against splash and fumes throughout the entire mill.

The coatings discussed will include chlorinated rubber, vinyl, liquid neoprene, epoxy-amine coatings, asphaltic mastics and oil-base paints. It should be noted that the omission of other coatings in this discussion should not be interpreted as a condemnation of any specific product.

Selection

The main points that must be considered in the selection of any coating are: (1) Relative resistance of the product to the environment, (2) Ease of application, (3) Experience under similar conditions of exposure, (4) Cost per year of the applied coating and (5) Choice of colors. An attempt has been made to provide such information in Table 1.

An examination of these empirical data will show that with the exception of oil base paint, almost any of the coatings listed are satisfactory for service with water or aqueous solutions of salts or alkalis. However, chlorinated rubber, vinyl and epoxy coatings are preferred for acid exposure.

Few coatings are satisfactory in chlorine or chlorine dioxide atmospheres. As shown in Table 1, chlorinated rubber and vinyl coatings usually are selected for such oxidizing environments.

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Abstract

Practical information is given on the selection and use of protective coatings in the pulp and paper industry. The main points to be considered in the selection of any coating are relative resistance of the product to the environment, ease of application, experience under similar conditions of exposure, cost per year of the applied coating and choice of colors. Information of this kind is given for the following materials: chlorinated rubber, vinyl, liquid neoprene, epoxy-amine, asphaltic mastic and oil base paints. Also included is information concerning the resistance of these coatings to a number of acids, alkalis, acid salts, alkaline salts, neutral salts, gases and organic materials.

The importance of good surface preparation is discussed. Recommendations are made concerning the application of coatings. Properties of specific coating materials are given and typical specifications listed. **545**

All the coatings under discussion have good weather resistance. Obviously, coatings such as neoprene and epoxy materials that must be compounded on the job are not as readily applied as one package systems. Asphalt mastics are usually applied with special high pressure spraying equipment, but most of the other coatings listed may be applied by brush, spray or roller coater.

When light colors are specified, the choice of coatings is restricted inasmuch as neoprene and asphalt are generally too dark in color. However, it is often possible to use neoprene as a base coat followed by a light colored chlorinated rubber coating. The use of a two color coating system has the additional advantage of assuring a more complete coverage.

With the exception of epoxy coatings and oil base paints, all products listed in Table 1 have been used successfully for more than ten years in the pulp and paper industry. Similar experience records can be anticipated for epoxy-amine coatings in the future, but experience data with this new type of coating are limited at the present time.

Most engineers and maintenance men know that the cost of paint cannot be determined solely by the cost of a gallon of a proprietary coating. They also recognize that the materials cost is but a small fraction of the total coating installation cost. Hence, they are interested in economy of performance (i.e., cost per year). Experience has shown that most of the coatings listed will cost less than many so called cheaper products when this criterion is used.

More specific information on the chemical resistance of typical coatings is given in Table 2. It is suggested that these data be used for guidance only and not as a substitute for exposure information under actual conditions of service.

While typical top quality coatings have been com-

pared generically, it must be admitted that identification by a generic name is no guarantee of quality. Coatings should be purchased on specification from reliable coatings manufacturers. It is false economy to select a protective coating without knowing its solids content and the resin content of the solids. Such information is provided under the description of properties of specific coating materials.

Surface Preparation

Regardless of high cost of sandblasting and unfilled hopes for miracle surface preparation proce-

dures, all metal surfaces should be prepared properly and meticulously. In spite of many investigations of simpler methods, all reliable authorities insist that sandblast cleaning must be used whenever possible. A No. 2 commercial finish should be provided but a No. 3 finish sometimes is acceptable for maintenance work.⁷

Unfortunately, the latter condition is seldom approached in practice because of difficulties associated with sandblasting and lack of insistence on adequate surface preparation when other cleaning methods are used. However, regardless of claims to the con-

TABLE 1—Protective Coating Selection Chart for the Paper Industry¹

	Relative Resistance						Relative Ease of Application	Relative Success in Paper Industry	Relative Cost per Year	Color Possibilities	Total
	To Water	To Salts	To Alkalies	To Acids	To Oxidizing Gases	To Weather					
Chlorinated Rubber.....	10	10	10	9	6	7	8	10	8	10	88
Vinyl.....	10	10	10	9	7	8	8	7	10	8	87
Liquid Neoprene.....	10	10	10	7	4	8	7	9	10	4	79
Epoxy-Amine.....	10	10	9	7	4	7	7	5	8	10	79
Asphaltic Mastic.....	10	10	8	7	2	7	6	10	7	2	69
Oil Base Paint.....	7	6	3	4	1	9	10	5	3	10	58

¹ Relative index values are rated from 1—10 with 10 being the most desirable.

TABLE 2—Resistance of Coatings to Chemicals in the Paper Industry¹

	Chlorinated Rubber		Vinyl		Liquid Neoprene		Epoxy-Amine		Asphalt Mastics		Oil Base Paints	
	75 F.	150 F.	75 F.	150 F.	75 F.	150 F.	75 F.	150 F.	75 F.	150 F.	75 F.	150 F.
Acids:												
Acetic, 10%.....	F	N	F	N	F	N	E	P	F	N	N	N
Acetic, glacial.....	N	N	F	N	N	N	E	E	N	N	N	N
Formic, 90%.....	N	N	N	N	N	N	E	E	N	N	N	N
Hydrochloric.....	E	E	E	E	N ²	N ²	E	E	N	N	N	N
Hypochlorous.....	E	G	E	E	N	N	P	N	G	E	N	N
Lactic.....	E	E	E	E	E	E	E	E	N	N	N	N
Nitric.....	E	F	E	E	F	N	E	E	F	N	N	N
Oleic.....	N	N	E	E	F	N	E	E	E	N	N	N
Oxalic.....	E	N	E	E	E	N	E	E	E	N	N	N
Perchloric.....	F	N	E	E	E	N	E	E	E	N	N	N
Phosphoric.....	F	N	E	E	E	N	E	E	E	N	N	N
Sulfuric, 50%.....	E	F	E	E	E	F	E	E	E	N	N	N
Sulfuric, 70%.....	G	N	E	G	N	N	F	N	N	N	N	N
Sulfuric, 93%.....	N	N	E	G	N	N	N	N	F	N	N	N
Alkalies:												
Ammonium Hydroxide.....	E	E	E	P	E	E	E	E	E	G	N	N
Calcium Hydroxide.....	E	E	E	P	E	E	E	E	E	G	N	N
Potassium Hydroxide.....	E	E	E	P	E	E	E	E	E	G	N	N
Sodium Hydroxide.....	E	E	E	P	E	E	E	E	E	G	N	N
Acid Salts:												
Alum or Aluminum Sulfate.....	E	E	E	E	E	E	E	E	E	G	F	P
Ammonium Chloride, Nitrate, Sulfate.....	E	E	E	E	E	G	E	E	E	G	F	P
Copper Chloride, Nitrate, Sulfate.....	E	E	E	E	E	F	E	E	E	G	F	P
Ferric Chloride, Nitrate, Sulfate.....	E	E	E	E	E	F	E	E	E	G	F	P
Zinc Chloride, Nitrate, Sulfate.....	E	E	E	E	E	N	E	E	E	G	F	N
Alkaline Salts:												
Sodium Bicarbonate.....	E	E	E	E	E	E	E	E	E	E	G	P
Sodium Carbonate.....	E	E	E	E	E	E	E	E	E	E	G	N
Sodium Sulfide.....	E	E	E	E	E	E	E	E	E	E	G	N
Trisodium Phosphate.....	E	E	E	E	E	E	E	E	E	E	N	N
Neutral Salts:												
Calcium Chloride, Nitrate, Sulfate.....	E	E	E	E	E	E	E	E	E	E	G	G
Gases:												
Chlorine, Dry.....	F	N	N	E	N ³	N ³	F	N	F	N	N	N
Chlorine, Wet.....	N	N	E	E	N ³	N ³	E	N	N	N	N	N
Sulfur Dioxide, Dry.....	E	E	E	E	E	E	E	E	E	E	N	N
Sulfur Dioxide, Wet.....	E	E	E	E	E	E	E	E	E	E	N	N
Organic Materials:												
Acetone.....	N	N	N	N	N	N	E	P	N	N	N	N
Alcohol, Methyl, Ethyl.....	E	E	E	E	E	F	E	E	E	E	N	P
Carbon Tetrachloride.....	N	N	N	N	N	N	E	E	E	E	N	N
Formaldehyde, 37%.....	E	E	E	E	E	N	E	E	E	E	N	N
Trichloroethylene.....	N	N	N	N	N	N	E	F	N	N	N	N
Other Materials:												
Kraft Liquor.....	E	E	E	E	E	E	E	E	E	G	N	N
Black Liquor.....	E	E	E	E	E	E	E	E	E	G	N	N
Green Liquor.....	E	E	E	E	E	E	E	E	E	G	N	N
White Liquor.....	E	E	E	E	E	E	E	E	E	G	N	N
Sulfite Liquor.....	E	E	E	E	E	N ³	E	E	E	N	N	N
Chlorite Bleach.....	G	F	E	E	N	N	P	N	N	N	N	N
Chlorine Dioxide.....	G	F	E	E	N	N	F	N	N	N	N	N

¹ Ratings are as Follows: E—No attack; G—Appreciably no attack; F—Some attack but usable in some instances; P—Attacked—not recommended; N—Rapidly attacked.

² Permeation with concentrated solutions. Plant tests required before use.

³ Surface hardening. Plant tests required before use.

trary, the recommendations of NACE Committee TP-6G must be followed. All loose scale, rust, grease and superficial dirt must be removed.

Compromises in surface preparation must be held to a minimum and it must be remembered that securing at least a No. 3 finish is one of the most important points to consider prior to the application of a protective coating.

Most maintenance men who have attempted to apply protective coatings to old equipment have recognized the importance of good design. The presence of sharp edges, projections and deep crevices makes maintenance costly. Whenever possible, the objectionable features should be avoided in the design of all paper mill equipment.

This equipment can be protected most readily and economically when first installed. When the surface is properly prepared and covered by an adequate thickness of a properly selected protective coating, one good sandblasting operation may be sufficient for the entire useful life of the equipment. Subsequent coats of a similar coating usually may be applied from time to time provided the old surface is clean and no bare metal is exposed.

Application Data

Dust and grease must be removed before the application of the first coat of any protective coating system. This coat must be applied within a few hours after surface preparation. Experience has shown that it is advantageous to apply a wash primer before the application of almost any protective coating.

Regardless of whether or not an additional primer is used with the protective coating system, a minimum of three coats of the protective coating must be applied. The total thickness must be at least five mils. Obviously, additional coats or additional thicknesses of any properly selected coating will pay dividends.

The average thickness can be determined through the use of various magnetic thickness gages, such as the Elcometer or the G. E. gage. The thickness of the film will be governed by the solids content and application method used. The data on the solids obtained from various coatings by casting films are given as specifications under properties of specific coatings. However, because of irregularities in surfaces and other practical application considerations, the coverage or spread will vary from 60 to 85 percent of the optimum coating thickness shown in the specifications.

Holidays or discontinuities must be avoided. While these can be detected readily by the use of high frequency spark testing equipment, such techniques should be used only by an experienced operator. Otherwise, holes may be burned through thin areas of the coatings.

A so-called non-destructive tester having an ap-

plied potential of less than 70 volts is now available. The inspection electrode supplied with this equipment consists of a damp cellulose sponge which is brushed over the coated surface. A ground wire is clamped to the bare metal surface and an alarm is activated whenever a flow of current occurs as a result of contacts with imperfections or pinholes.

All protective coatings under discussion consist of solutions or dispersions of film-forming resins in organic solvents. Most solvents used with coatings are toxic and flammable. Hence, exposure to flames or sparks during the application must be avoided. Also, the coatings should not be applied in confined areas unless the applicator is properly protected from inhaling the fumes.

Properties of Specific Coating Material

Chlorinated Rubber

Chlorinated rubber coatings are the oldest quality commercial synthetic protective coatings available today. They were introduced more than 30 years ago in Germany and have been used almost continuously since that time. They adhere tenaciously to concrete and may be used on properly prepared metallic surfaces in the absence of special primers.⁸ Specifications for a typical protective coating based on chlorinated rubber are given in Table 3. One gallon of this coating should cover a minimum surface of 80 square feet to provide a built up coating 5 mils thick.

Chlorinated rubber base coatings are available in a fairly wide color range. They have excellent resistance to alkalis and have been used successfully for more than 20 years in the pulp and paper industry.

Vinyl Coatings

Most vinyl coatings are based on copolymers of vinyl chloride, in which vinyl chloride is the main component. Vinyl coatings are usually applied over a vinyl primer system, although proprietary vinyl coatings, which give good adhesion to sandblasted steel and clean concrete surfaces are available.

Properly compounded vinyl coatings are resistant to splash and fumes from most corrosives used in the pulp and paper industry. As is the case with chlorinated rubber coatings, vinyl coatings are available in a wide variety of colors. They have been used successfully in the pulp and paper industry for approximately fifteen years.⁹

A typical specification for a general purpose vinyl protective coating is given in Table 4. One gallon of this coating should cover a minimum surface of 75 square feet to provide a built up coating 6 mils thick.

Liquid Neoprene

Coatings based on a two package compounded liq-

TABLE 3—Typical Specifications for a Protective Coating Based on Chlorinated Rubber

Solids Content	37.5-45 percent
Specific Gravity	1.05-1.2
Viscosity at 77 F	250-600 cps

TABLE 4—Typical Specification for a General Purpose Vinyl Protective Coating

Solids Content	27.5-35 percent
Specific Gravity	0.875-0.975
Viscosity at 77 F	200-500 cps

liquid neoprene system have been used successfully in the pulp and paper industry for ten years. Since the components must be mixed just before use, this type of coating is not as convenient to use as some of the simpler coatings. However, the applied coating has superior resistance to abrasion, temperature and many corrosives. A liquid neoprene coating is more elastic than any other protective coating under discussion.^{10, 11}

Properly applied compounded liquid neoprene coatings are not recommended for use with concentrated hydrochloric acid but they have given excellent service with many other corrosives at temperatures up to the boiling point of water. For example, it is standard practice to line tank cars containing hot liquid caustic with liquid neoprene.

A typical specification for a heavy duty liquid neoprene coating is given in Table 5. One gallon of this material should yield a coating at least five mils thick when applied to 140 square feet of surface.

Because some maintenance men object to compounding materials on the job, a one package liquid neoprene maintenance coating system has been introduced. This product has superior corrosion resistance to many other protective coatings, but is inferior to the coating obtained from the two package neoprene system.¹²

A typical specification for a maintenance neoprene coating is given in Table 6. One gallon should cover a minimum of 70 square feet to give a five mil thick built up coating.

The maintenance coating may be used directly on sandblasted steel or clean concrete. However, the heavy duty compounded neoprene requires a chlorinated rubber priming system for best results. While many different dark colors could be provided, it is customary to supply liquid neoprene coatings in gray and black colors only.

Epoxy-Amine Coatings

Epoxy-amine coatings which were introduced commercially about five years ago are characterized by excellent adhesion to sandblasted surfaces and good resistance to temperature and impact. These products are much more resistant to mechanical damage than furan and phenolic resin coatings and are replacing them in many instances. As was the case with the previously described heavy duty neoprene coatings, epoxy-amine coatings must be compounded on the job. It is possible to prolong the shelf life of

the compounded material by keeping it cool prior to application.^{13, 14}

A typical specification for a room temperature curing epoxy resin coating is given in Table 7. One gallon of compounded coating, when applied as a three coat system, should give approximately six mils thickness on 100 square feet of surface.

While there are fewer case histories on the use of epoxy resin coatings in the pulp and paper industry, it may be predicted that this type of product will prove to be as satisfactory as other standard coatings under discussion. Epoxy-amine coatings are available in a wide range of colors.

Asphaltic Mastics

Many of the so-called asphaltic mastics are based essentially on gilsonite-asphalt blends compounded with mica. These coatings are usually sprayed under high pressure and are built up to thicknesses of at least 60 mils. While these products are not resistant to solvents or oxidizing agents, they have given excellent service in many applications in pulp and paper mills.

A typical specification for an asphalt mastic is given in Table 8.

Oil Base Paints

Oil base paints are used to a large extent for decorative purposes. In spite of their resistance to sunlight and weather, they are not sufficiently resistant to chemicals to warrant consideration in the pulp and paper plants except for the protection of storage and office buildings.

Conclusion

With the exception of oil base paints, most coatings under discussion may be used for many general applications in the pulp and paper industry. However, in specific instances, such as exposure to chlorine dioxide or chlorine, only those coatings having greatest resistance to these environments should be selected. Experience has shown that properly selected protective coatings when applied over clean sandblasted surfaces can solve many maintenance problems in the pulp and paper industry.

Acknowledgment

The assistance of the following persons in the preparation of this paper is greatly appreciated: J. Baum, Corrosion Resistant Products, Inc.; R. P.

TABLE 5—Typical Specification for a Heavy Duty Liquid Neoprene Coating

Solids Content	54-58 percent
Specific Gravity	1.1-1.2
Viscosity at 77 F	1750-2500 cps

TABLE 6—Typical Specification for a Maintenance Neoprene Coating

Solids Content	30-40 percent
Specific Gravity	1.0-1.1
Viscosity at 77 F	1400-1900 cps

TABLE 7—Typical Specification for a Room Temperature Curing Epoxy Resin Coating

Solids Content	65-75 percent
Specific Gravity	1.1-1.2
Viscosity at 77 F	800-1100 cps

TABLE 8—Typical Specification for an Asphalt Mastic

Gilsonite-Asphalt	30-45 percent
Non-Volatile Materials	65-75 percent
Pure Petroleum Solvents	25-35 percent
Viscosity at 77 F	300,000-450,000 cps

Desch, Armstrong Cork Co.; E. A. Erich, Tube Turn Plastic Co.; J. D. Fenstermacher, Atlas Mineral Products Co.; J. H. Fry, Dixie Cup Co.; D. H. Reinhart, Metalweld, Inc.; R. H. Steiner, Naugatuck Chemical Co.

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**Any discussions of this article not published above
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TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

The Effect of Purification of Commercial Sulfonates On Their Corrosion-Stain Property*

By HARRY C. MUFFLEY, VAN HONG and DAVID BOOTZIN

Introduction

IT IS A COMMON practice to blend small concentrations of sulfonates with petroleum base oils or petrolatums in the preparation of corrosion preventive lubricating oils and compounds. As a rule the addition of a small amount of inhibitor enhances the protective ability of the compound. In some cases, however, the formation of stain which is not identified as a conventional corrosion product produced from the oxidation of metal has been observed.

Stain and corrosion as encountered on Ordnance material in storage are old problems to a number of government laboratories.^{1,2,3} Baker⁴ of the Naval Research Laboratory reported that the presence of hygroscopic impurities in the alkaline and alkaline earth sulfonates contribute to corrosion.

In the course of investigating this stain-corrosion phenomena the Rock Island Arsenal laboratory found that some proprietary rust preventive compounds containing sulfonate type inhibitors were detrimental to the preserved material because of the formation of stain. Unpublished work by Hong showed that this type of inhibitor can be screened out by a corrosion-stain test method. Hong further postulated that the presence of low molecular weight sulfonates, oxidizable additives, and water soluble inorganic compounds in these preservative materials might be the contributing factor for the formation of stain-corrosion. This laboratory undertook the purification of this type of inhibitor to enhance its preservative properties, separate any undesirable components, and identify the products obtained.

A literature survey revealed several methods of separation and purification of the sulfonate type compounds. It is a well known fact that the preparation of organic sulfonates of sufficient high purity is a difficult process which necessitates the use of complicated techniques involving the separation of oil-soluble and water-soluble sulfonates.

A large number of the procedures reviewed employed the extraction technique utilizing some type of organic solvent such as ethylene glycol monoethyl ether,⁵ isobutyric acid,⁶ butyl alcohol,⁶ isopropyl alcohol,⁷ and amyl alcohol.⁸ Because of their water solubility they are not applicable for the separation of oil-soluble and water-soluble sulfonates.

The method presented by Brooks et al⁹ differs fundamentally from the other extraction methods in that the sulfonates are converted to the sulfonic acid prior to the extraction with a solvent.

The percolation and contact absorption method mentioned by Wilson¹⁰ requires an elaborate set-up of equipment and is time consuming as compared to the extraction methods.



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Abstract

Sulfonates are used to a great extent in the preparation of corrosion preventive lubricating oils. Investigations were conducted to determine whether the staining characteristics of commercial sulfonates could be eliminated by purification and to identify the material causing the stain.

An extraction procedure produced a sulfonate that caused less staining than the original commercial sulfonate. The materials causing the stain were water soluble sulfonates and inorganic salts.

5.5.3

The extraction method of separation was considered the more applicable procedure if a water-immiscible solvent were used that would dissolve the sulfonate and if it had a low boiling point to expedite the removal of the solvent. A solvent of this type would

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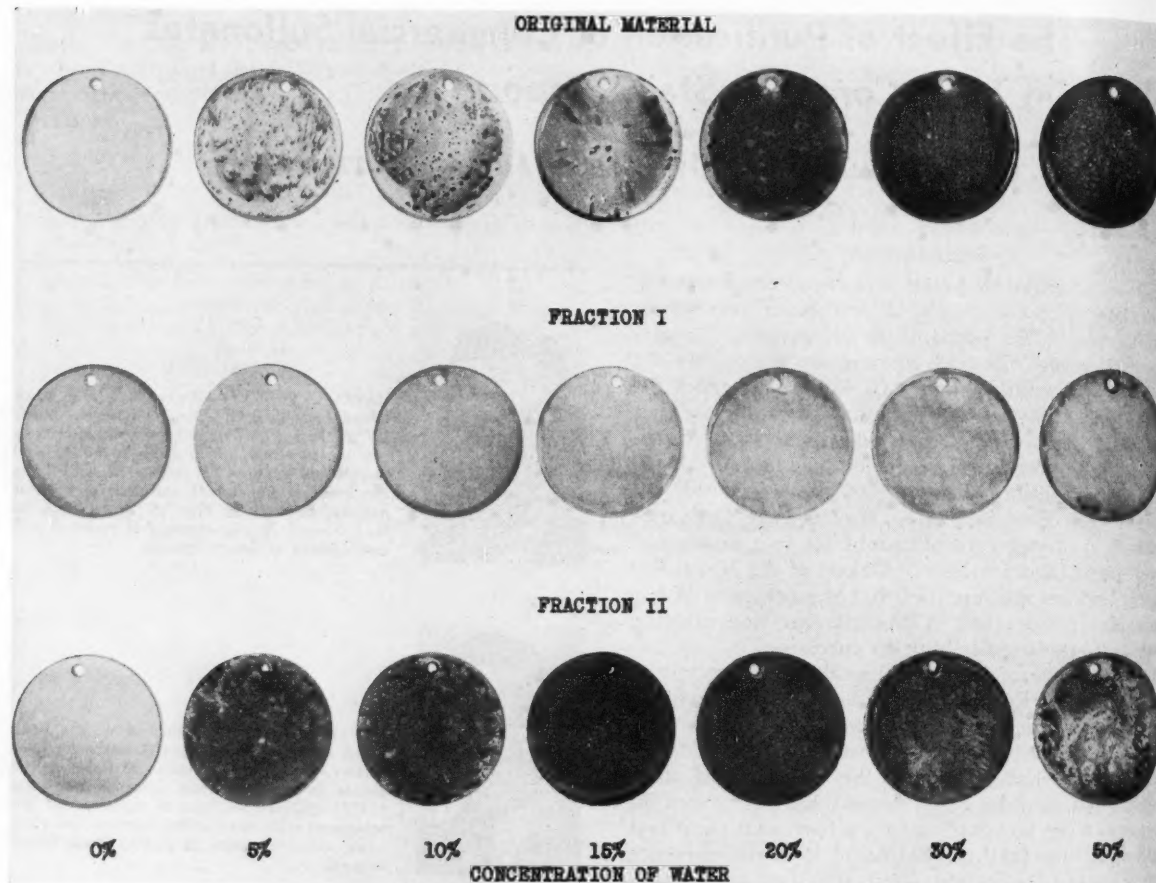


Figure 1—Samples used in Rock Island Arsenal corrosion stain test of Material No. 78A.

tend to eliminate the water from the sulfonate and the water soluble material which could be the cause of the staining.

Procedure and Results

The commercial sulfonates received at this laboratory were dissolved in oil to facilitate the ease of shipping and manipulating in the laboratory. It was necessary therefore to de-oil the material before the sulfonates could be investigated and evaluated. A modification of the de-oiling procedure as given by the ASTM¹ for the "Analysis of Petroleum Sulfonates" was used to de-oil the commercial sulfonates appearing in Table 1.

This modified de-oiling procedure involved dispersing the commercial sulfonate in 50 percent isopropyl alcohol water solution and extracting with petroleum ether to remove the oil. The alcoholic solution was concentrated to one-fourth the original charge by conventional distillation methods; this left approximately 5 percent of the isopropyl alcohol undistilled. Precautions were taken in each step not to heat the material above 120 C. Air was injected through a capillary tube into the solution to prevent ebullition.

The purification of the sulfonate was undertaken by extracting the alcohol sulfonate solution with

TABLE 1—Composition of the Original and Purified Sulfonate and their Solubility in Water

Material No.	Description of Material	Yield by Purification, Percent	Solubility In Water ²
66	Sodium "mahogany" sulfonate.....	62 ²	25
	Fraction I.....	58.2 ³	3
	Fraction II.....	1.3 ⁴	
77	Sodium sulfonate, synthetic.....	47.2	25
	Fraction I.....	43	2
	Fraction II.....	3	
78A	Sodium sulfonate, synthetic.....	56	25
	Fraction I.....	42	1
	Fraction II.....	13	
92	Sodium sulfonate, mixture of synthetic and mahogany.....	60	25
	Fraction I.....	53	2
	Fraction II.....	2	

¹ Ml of water required to dissolve 0.5 grams of the material.

² Original sulfonate analysis furnished by the company.

³ Purified fraction.

⁴ Water-soluble fraction.

toluene. The extracts were combined and concentrated by distillation to a thick syrup, then transferred to an oven to dry. This material was identified as Fraction I. The water layer containing the non-extractable material was dried and designated as Fraction II.

A comparison of the yield of the various fractions in Table 1 with the sulfonate content, as stated by the company, indicates that a certain amount of ma-

material was removed from the original compound by this extraction.

The detection of sulfonate by the spot test technique worked out by Feigle and Lenzer¹² was used in identifying the products obtained from the extraction procedure. This technique depends upon the replacement of the sulfonate group by a hydroxyl group with the formation of sodium sulfites. Upon acidifying the sulfite, sulfur dioxide is liberated which is detected by the induced oxidation of green nickel (II) hydroxide to black nickel (III) hydroxide. Both fractions of the four compounds gave positive results for the presence of sulfonate.

A comparison of the spectrographic analysis of both fractions and the original material of the four compounds revealed the presence of the highest concentration of inorganic material in Fraction II, less in the original material, and still less in Fraction I. This comparison was only an approximation, because the absolute values were not determined in the analysis.

The Fraction I material of the four compounds was readily soluble in the petroleum base oil. In water, however, it formed a colloidal suspension instead of a true solution. The reverse in solubility was observed with Fraction II being almost insoluble in oil but readily soluble in water. The results appear in Table 1.

The staining characteristic of the material was determined by the Rock Island Arsenal Corrosion-Stain Test. This test involves mixing samples of the materials with various percentages of water and smearing them on FS1020 steel specimens. Two samples are then sandwiched together and placed in a 180 F oven for 24 hours. They were then de-coated and inspected in direct fluorescent light.

In every case, the Fraction I material showed no stain or a slight over-all transparent film. The original material in most cases caused more intense staining than the Fraction I, particularly when the higher concentrations of water were used. The results of these tests appear in Table 2.

A more complete picture of the staining characteristics of Material No. 78A as shown in Table 2 was obtained by running the stain test on Fraction II of that material and including two additional water mixtures. The insolubility of Fraction II in oil made it necessary to dissolve it first in the calculated volume of water and then to disperse it in the oil in order to prepare the emulsified samples for test. Figures 1 and 2 show the improved staining characteristics obtained by processing Material No. 78A.

The extraction process in the majority of the cases improved the protective ability as indicated by the protection provided by the Fraction I materials in the Fog Cabinet. In the Army-Navy Humidity Cabinet two of the materials showed improvement and the other two gave approximately the same results as the original material. Each material, it should be noted, showed improvement in one or the other test media.

Discussion

In general the stained metal is considered by Rohrman¹⁴ as an altogether different metal from the un-

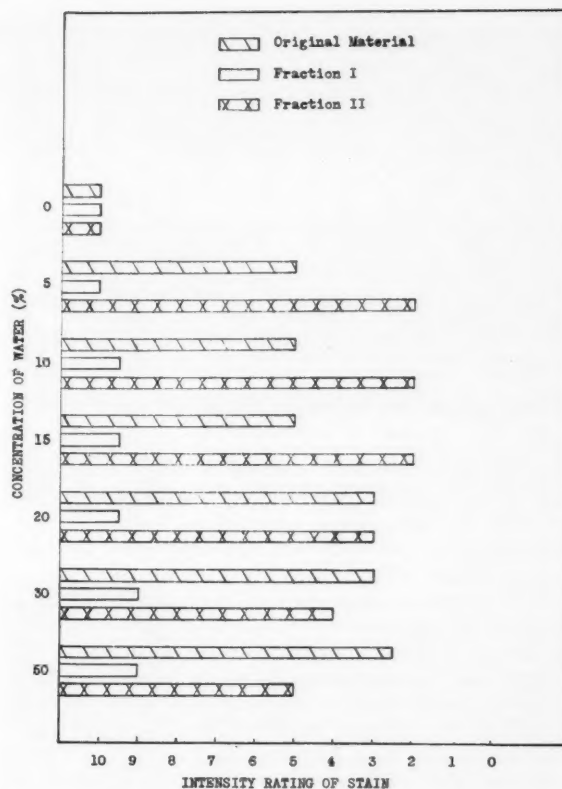


Figure 2—Comparison of the intensity of stain by Material No. 78A (sodium sulfonate, synthetic) in various concentrations of water.

TABLE 2—Rock Island Arsenal Corrosion-Stain Test Method Results

Material No.	Conc. of Water, Percent	Rating ¹ of Original Material	Rating of Fraction I	Rating of Fraction II
66.....	0	10	10	
	5	10	10	
	10	.9/A/7	O/A/9.8	
	20	.2/A/7-5	O/A/9.7	
77.....	50	.5/A/8	O/A/9.9	
	0	10	10	
	5	10	10	
	10	10	O/A/9.6	
78A.....	20	O/A/9.9	O/A/9.8	
	50	O/A/9.8	O/A/9.8	
	0	10	10	10
	5	.5/ds/5	10	O/A/2
92.....	10	.3/ds/5	O/A/9.5	O/A/2
	15	O/sA/5	O/A/9.5	O/A/2
	20	O/A/3	O/A/9.5	O/A/3
	30	O/A/3	O/A/9	O/A/4
99.....	50	O/A/3-2	O/A/9	O/A/5
	0	10	10	
	5	10	10	
	10	10	10	
100.....	20	.5/A/8	10	
	50	.9/A/7	10	

¹ First number 10 means no stain, O means overall stain, A = large area, d = dot, s = spot, last number = intensity of staining, 10 = no stain, 1 = very heavy stain or multiples thereof¹³.

stained metal in so far as corrosion is concerned. The stained area presents a place for corrosion reactions to start because that area has a greater tendency to go into solution.

It was the opinion of the authors that the cause of the stain was the presence in the inhibitor of impurities in the form of low molecular weight sulfonates

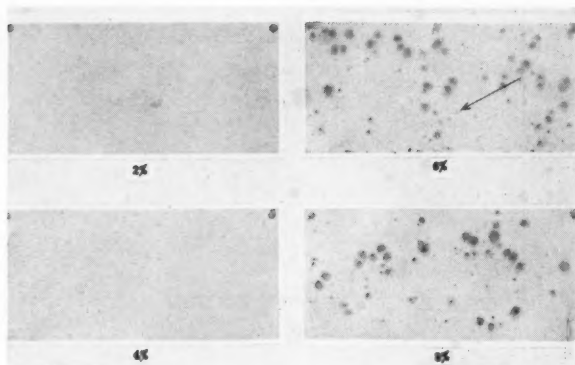


Figure 3—Typical micelle formation with different concentrations.

and inorganic salts. A portion of these impurities were separated out by extracting the de-oiled inhibitor with toluene. Their identity as sulfonates was established by the spot test, spectrographic analysis and solubility tests.

The extraction procedure in most cases improved the stain characteristics as indicated by the comparison of the original material with the Fraction I. The exception was Material No. 77 which is not significant because an over-all transparent film was obtained from both the original material and Fraction I; also the rating was done by the naked eye.

In the case of Material No. 78A the stain test was also run on the Fraction II material which caused more intense staining than either Fraction I or the original material. This was anticipated since it was thought that this material was the cause of the stain. Figure 2 gives an indication of the different intensities of stain of the two fractions and the original material.

The extraction procedure improved the protective ability of three of the four materials when tested in the Fog Cabinet, but only two of the four showed improved protection in the Army-Navy Humidity Cabinet. It is conceivable that the unpredicted results were due to a combination of effects such as

difference in test media or micelle formation.

The work of Arkin and Singleterry¹⁵ established that petroleum sulfonates, oil-soluble soaps, existed predominantly in a micellar form in hydrocarbon solvents. Bondi¹⁶ further states that with the first appearance of micelle the degree of association increases very rapidly. It was observed in each micelle formation that a nucleus of rust was detected in the materials that failed (see Figure 3).

An over-all look at the results indicate that the Fraction II material contributed to the stain of the metal surfaces. By removing the low molecular weight sulfonates and inorganic salts by the extraction procedure, improved staining characteristics and protective properties of the commercial inhibitors were obtained. The greatest improvement was noted in Material No. 78A in which the largest yield of Fraction II was obtained.

Note: The opinions or assertions contained herein are not to be construed as being official or reflecting the views of the Department of the Army.

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Application of Cathodic Protection to 48 Well Casings And Associated Production Facilities at Waskom Field*

By G. L. DOREMUS, W. W. MACH and J. J. LAWNICK

Introduction

WASKOM FIELD lies principally in southeastern Harrison County, Texas and extends into Caddo Parish, Louisiana. The field is formed by an anti-clinal feature, one of several, superimposed on the Sabine uplift. Apex of the local structure is situated about one mile southwest of Waskom, Texas. It is separated from the Bethany gas field, some four miles to the south in Panola County, by a low structural saddle (Figure 1).

Shallow gas production was begun in 1924. A total of about 225 wells have produced gas from the shallower reservoirs. These reservoirs, the Nacatoch, Blossom, Barlow and Florsheim, all above 3,000 feet, have long been considered essentially depleted with most of the wells being abandoned.

Production below the Massive Anhydrite was started in 1938 from the Hill zone, a Rodessa member. Principal production today is from the Hill, Upper Pettet and Travis Peak zones. Travis Peak oil production got under way in 1946. At present there are approximately 170 gas wells and 90 oil wells producing in the field.

A typical casing program involves approximately 1,000 feet of 9 $\frac{5}{8}$ -inch or 10 $\frac{3}{4}$ -inch surface casing with cement returned to the surface. Less than this amount of surface casing was set in some cases after permission had been obtained from the Texas Railroad Commission. The production casing is usually 5 $\frac{1}{2}$ -inch cemented at approximately 6,000 feet with 200 to 400 sacks of cement. Two and three-eighths inch tubing ordinarily is hung on a packer set just above the producing horizon; in the case of dual completion, it usually is set between the producing sands.

La Gloria Oil and Gas Company owns and operates a group of 48 wells in the central portion of Waskom Field (28 oil, seven gas, eight dual completion, one salt water supply, and three injection wells, with one well temporarily abandoned). It is with external corrosion experienced by these well casings and mitigative measures applied for corrosion control that this paper is principally concerned.

Corrosion History

As a result of corrosion failure occurring in April, 1954, the production casing of one well was pulled and repaired to a depth of 2,536 feet. The section of casing from 1,013 feet to 1,561 feet, most of which was opposite the Nacatoch sand (Figure 2), was severely pitted as a result of external corrosion. Penetration had occurred at 1,414 feet and a trace of corrosion was found to a depth of 2,506 feet. Cost of this casing repair job was estimated to be \$22,000, exclusive of lost production. Age of the well at time of failure was less than five years.



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Abstract

Casing failures caused by external corrosion attack led to an engineering study to obtain design data and costs for a multiple rectifier type cathodic protection system for 48 wells. This protective system was subsequently installed in an effort to prevent further costly casing repairs.

Difficulties encountered in obtaining the desired current drain of 1.5-2.0 amperes from each well and solutions to these problems are discussed. In final form the multiple rectifier installation provided all protective current for approximately 75 percent of the wells, while magnesium anodes were used exclusively or in supplement to rectifier drainage for the remainder.

All of the coated gas lines, an appreciable portion of the bare oil gathering lines, and most of the production storage tank bottoms in the field were necessarily included in the cathodic protection system. In addition a separate rectifier-graphite anode system with new design features was installed for protection of an emulsion treater and brine handling equipment associated with a waterflood project in the field. 5.2.1



Figure 1—Geographic location of Waskom Field.

A study of the problem throughout the field was immediately initiated. Two additional casing leaks were found on other wells, one at a depth of 2,130 feet and the second at 1,500 feet. These wells also were less than five years old. Cost of these repairs averaged \$4,000 per well. Furthermore, oil production from one well, a dual completion, was lost; this contributed substantially to the overall financial loss caused by these corrosion failures.

In addition to the above mentioned well difficulties, inspection of the emulsion treater at the central storage area revealed very active corrosion of those internal surfaces in contact with brine. Failure of several brine lines in the water flood system from internal corrosion also was reported. Brine produced for this flood is characterized by low resistivity (approximately 5 ohm-cm), saturation with sweet gas, and absence of bacterial activity.

Preliminary Cathodic Protection Survey

In the face of the prospect of ever-increasing casing repair costs, the decision was made to seek a possible solution to the severe casing corrosion problem through the use of cathodic protection. Accordingly, in July, 1954, an engineering survey was made to determine the current requirements for and economic feasibility of cathodic protection for La Gloria's wells in Waskom Field.

During this survey, two wells were disconnected from flow lines and normal casing potential profiles were run with an internal tool having spring loaded contactors on 25 foot spacing. On one well, Downer No. 2, these runs were repeated with one ampere and two ampere current drains at the well head, using the disconnected gas flow line as a temporary ground bed.

Results of these tests are shown graphically in Figure 2. Effect of current drain was noticeable to

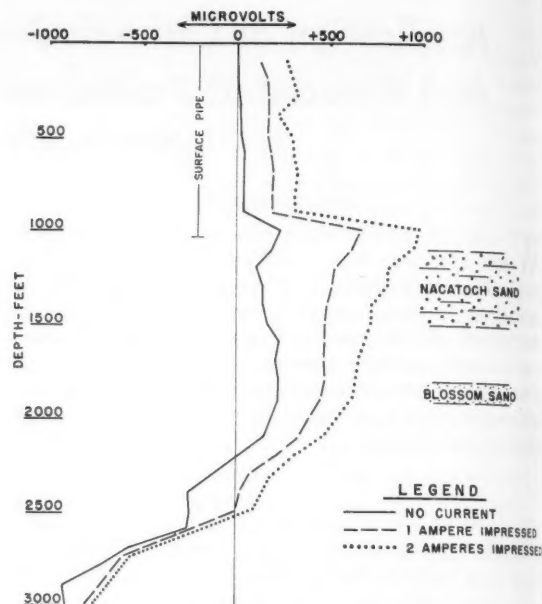


Figure 2—Results of casing potential profile tests.

2500-3000 foot depth. Good shifts were produced through the troublesome Nacatoch and Blossom formations, where the casing failures had occurred.

Although not depicted in Figure 2, a general anodic area was shown by the casing profile starting at 2900 feet and extending downward for almost 3000 feet; neither of the test current drains had much effect on the casing profile at these greater depths.

The so-called "surface pipe effect" is quite evident in the two test current profiles. By calculation from casing and surface pipe conductances, it could be shown that the current split at the bottom of the surface pipe corresponded exactly to that which would be predicted if metallic contact existed at that point.

In consideration of the fact that all casing failures to date have occurred in the shallower zones where substantial shifts were produced in the casing profile by the test currents, a 1.5–2.0 ampere drain was selected as optimum for protection of well casings in Waskom Field. It was decided to proceed with the design of a cathodic protection system capable of supplying this range of current for all 48 wells included in the survey.

Figure 3 shows the general layout of these wells, the associated gas and oil lines, and existing AC power lines in the area at time of survey.

Multiple Rectifier Ground Bed Design

Detailed soil resistivity tests and availability of power at several locations in the field supported the selection of a multiple rectifier-ground bed installation as being the most economical source of protective current, provided good use could be made of gas and oil lines from the wells for current distribution. The gas flow and gathering lines almost without exception were of all welded construction, coated and buried. The oil lines on the other hand were

generally bare, screw coupled and laid on the surface. The fact that the top few inches of soil were very sandy, and consequently of very high resistivity, was considered favorable in that current pick-up by the bare oil lines would likely be limited to reasonable levels. Sub-surface soils ranged from less than 1000 ohm-cm to more than 100,000 ohm-cm in the vicinity of the wells. Typical values for the area are 5000-10000 ohm-cm.

Welding generator tests at several locations indicated reasonably good current spread from the drain point to wells in the area via the electrical path provided by the gas and oil lines. It was not possible, however, to insulate the wells prior to the survey. The degree of protective current spread which could be realized from the ultimate rectifier installation, where control of current drain at each well would be possible, could only be estimated from the data obtained.

Cathodic protection design for the wells was based on a total drain of 170 amperes to be provided by four air cooled selenium rectifiers as shown on Figure 3. These units were individually rated at 30, 40, 40, and 60 amperes, respectively. Rectifier driving voltages ranged from 18 to 28 volts with graphite anode ground beds designed accordingly, resulting in maximum loads from $1\frac{1}{2}$ to 3 amperes per 3-inch x 60-inch anode. These rectifier locations were more or less dictated by power availability, as indicated on Figure 3. They were not considered 100 percent ideal from a distribution standpoint.

Fortunately, very few foreign pipe lines were found in the field, and it was possible to select ground bed locations which were considered unlikely to lead to serious interference problems. It was recognized, however, that interference tests and possible bonds were to be considered a necessary phase of any subsequent cathodic protection installation project. During the survey, selection of the sizes and types of insulation materials required for isolation of all wells from connecting lines was made.

Cost Estimates

Cost of the proposed cathodic protection system for all wells, and to large degree the connecting oil and gas flow lines and production tank settings, was estimated to be \$11,583, including well insulation. Calculated probable power load from all units was 3.54 KW, estimated to cost \$92 per month at prevailing local rates.

Also included in the cathodic protection survey were the emulsion treater and brine storage and processing vessels in the water flood project at the field. They were included even though no corrosion failures had been experienced up to that time. A design was laid out for the 6-foot x 27-foot vertical treater, two 500-barrel storage tanks, a 6-foot x 5-

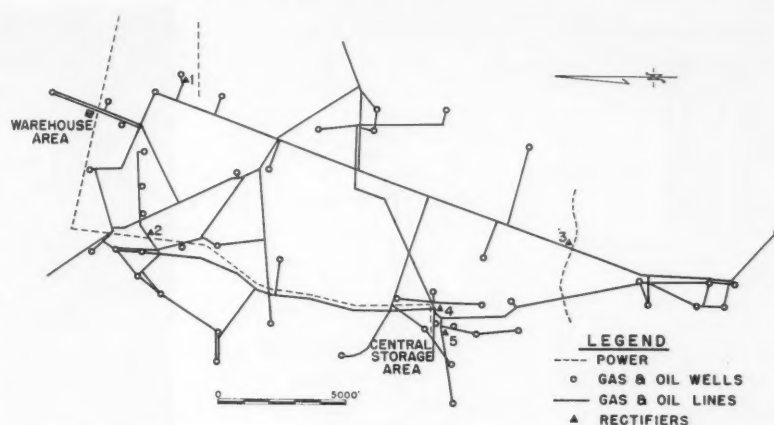


Figure 3—Layout of La Gloria's wells in Waskom Field. Note location of principal pipe lines, AC power and Rectifiers 1-5.

foot filter and a 6-foot x 5-foot accumulator. Design was based on providing a current density of 10 milliamperes per square foot on all internal surfaces in contact with brine, using a single 6 volt, 25 ampere rectifier (No. 5 in Figure 3) and a total of 13 individually controlled 3-inch x 60-inch oil treated graphite anodes in the several vessels. Estimated cost of this installation was \$1,704.00, with a calculated probable power load of 0.30 KW and \$3.50 monthly operating cost.

In view of the reasonable estimated installation and operating costs for the cathodic protection systems, and the apparent ready payout to be realized from reduction of well casing repair costs, it was decided to proceed at once with the installation of cathodic protection.

Installation of Cathodic Protection—Phase 1

In March, 1955, Rectifiers 1-4 were installed with their associated ground beds as planned, and rectifier 5 was placed in operation for the treater and water flood vessels. Concurrently, all well heads were isolated with high pressure insulating unions or flanges; where dual completions were encountered, dual insulation was necessary.

The rectifier-ground bed installations were constructed in accordance with customary cathodic protection practices. A typical pole mounted air cooled rectifier layout is illustrated in Figure 4.

At each well head bond wires were "cadwelded" to the well and to the adjacent flow line below grade and these wires were brought up inside a 2-inch pipe marker into a 6-inch x 6-inch x 4-inch galvanized junction box. This box housed a 0.01 ohm shunt and resistance wire as necessary for ultimate control of current drain from the well head. Figure 5 shows a typical dual completion well hook-up, with pipe marker and junction box located next to the oil flow line for protection. Figure 6 shows a close-up of the junction box at this location. This method of handling the bonding wires and circuit elements was considered essential to avoid possible damage in the course of disconnecting, testing and reworking the wells from time to time.

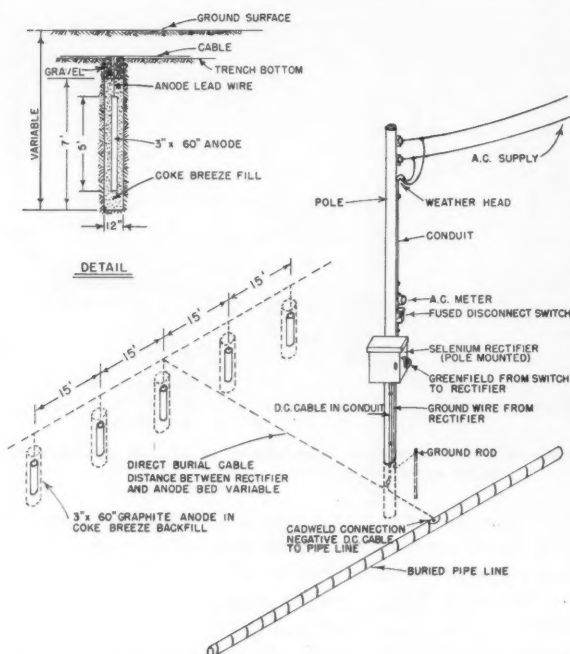


Figure 4—Typical air cooled rectifier-graphite anode ground bed installation.

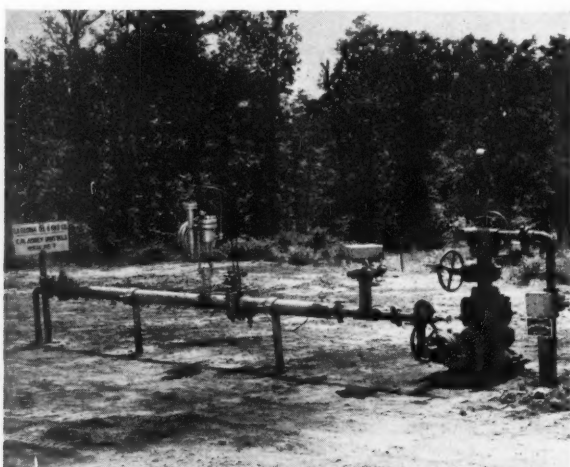


Figure 5—Dual completion well showing enclosure for drainage leads, shunt and resistance wire.

In addition to well head bonding, a number of cross bonds between oil and gas lines were made after energization of the rectifiers to achieve the best possible current distribution from the four rectifier drain points. The screw coupled, small diameter oil lines (2-inch and 2½-inch) proved both troublesome and disappointing in that many high resistance joints had to be traced down and bonded, and IR drops in the lines rapidly reduced their effectiveness as drainage leads to remote wells. As a result, the coated gas lines were utilized for conductors wherever possible. In several cases, long sections of the bare oil lines were actually insulated off to conserve current for the wells.

After much testing, adjusting, bonding and isolat-

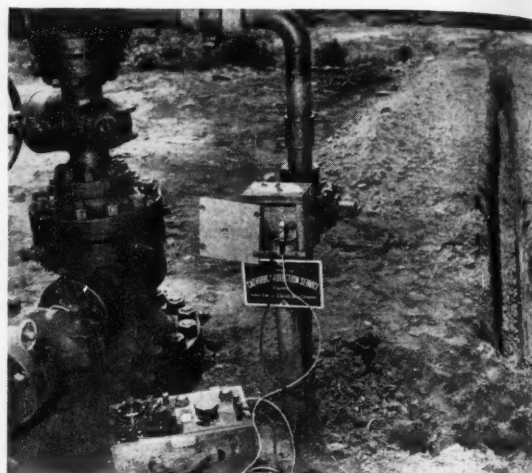


Figure 6—Close-up of drainage lead enclosure.

ing it became apparent that the existing flow lines provided inadequate electrical connections to attain the desired 1.5 amperes drain per well for all 48 wells. At this point, with a total rectifier drain of 170 amperes, 27 wells were receiving the desired minimum drain of 1.5 amperes, while the remaining 21 were only partially protected. This situation is more clearly illustrated in Figure 7.

Further tests showed that two small 35 volt, 9 ampere rectifiers at locations 6 and 7 would take care of an additional seven wells and that the balance of 14 wells could best be handled, either fully or in supplement to rectifier drainage, by use of the new high potential magnesium anodes. It was possible to locate a number of old mud pits. With the increased driving potential of the new type anode no great difficulty was anticipated in attaining 1.5 amperes drain from a group of twenty 17-pound anodes.

Concurrently with the foregoing, Rectifier 5 was mounted and graphite anodes were installed in the treater and water flood equipment at the central storage area. Five 3-inch x 60-inch anodes made up in special insulated through-the-wall mounts were installed horizontally in the treater. Three anodes were suspended from insulated deck mounts in each of the 500-barrel storage tanks, and one anode was installed vertically in the filter and another in the accumulator using through-the-wall type mounts. Negative and positive collector cables were run from the rectifier to each vessel. The outputs of the anodes were limited with individual resistance wire to that calculated to provide 10 milliamperes per square foot of internal tank surfaces. All anodes used were of oil impregnated type for operation in salt water.

A schematic diagram of this installation is presented in Figure 8. Figure 9 shows the rectifier and treater, with the graphite anode mounts faintly discernible in the three manhole cover plates. Two additional anodes were located in the burner section plate on the opposite side of the treater.

Installation of Cathodic Protection—Phase 2

In July, 1955, the two small 9 ampere rectifiers

were added as planned. One rectifier (No. 6) was connected to an existing meter serving unit No. 2 via a 1700-foot AC line extension, and the other (No. 7) was connected to an existing meter at the warehouse. This was done to minimize power costs and thus keep total operating costs within reason. Ground beds for these units consisted of twelve and eight 3-inch x 60-inch graphite anodes, respectively. These units performed as anticipated. Another seven wells were added to the list of those receiving the desired minimum current drain, and at this point the final group of installations involving magnesium anodes was started.

Magnesium anode installations were designed for 10-year projected life, and a rating of 80 milliamperes per 17-pound, high potential anode was selected for installation without prepared backfill. It appeared that best performance at minimum cost could be obtained by ditching four feet deep through old mud pits or waste disposal areas and installing the anodes horizontally in the bottom of this ditch. A minimum distance from the well head of 85 feet was maintained to give satisfactory vertical current distribution. The anode connecting cable (usually No. 4 copper, to minimize IR drop) was run over to the well head in a shallow ditch and brought up into the junction box at that point.

An experimental 20-anode installation of this type had been made at one well during the latter stages of Phase 1. In order to get full 1.5 ampere output resort was made to limited brine treatment of the soil in the anode area. Some four months later, after many substantial rains, the output of this group had increased slightly rather than decreased, and it was decided that resort to such treatment was justifiable where necessary. Preliminary work by others¹ had indicated that the high potential magnesium anode maintains good current efficiency at moderate current outputs in saline environment.

Accordingly, a total of nine wells were so protected with groups of twenty 17-pound anodes, using brine treatment as necessary to produce somewhat more than 1.5 amperes total output, whereupon current was restricted to 1.5-1.6 amperes with resistance wire. This procedure provided a small reserve in output which may be called upon at some later date should the resistance of the anode bed increase appreciably as a result of leaching. In each case the flow line was left fully insulated, and in fact many were "dead," having been purposely isolated to conserve rectifier current.

At the remaining 5 wells, where substantial but inadequate current drain existed from the rectifier system, magnesium anodes were added to supplement existing current and provide the needed 1.5 ampere total drain.

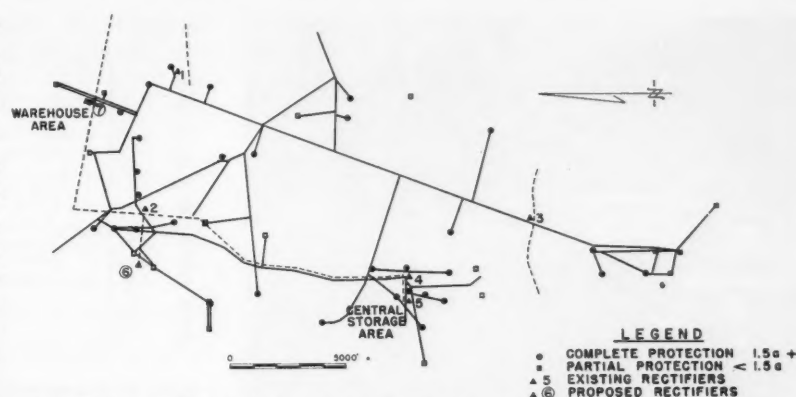


Figure 7—Layout of field showing status of cathodic protection after Phase 1 and proposed Rectifiers 6 and 7.

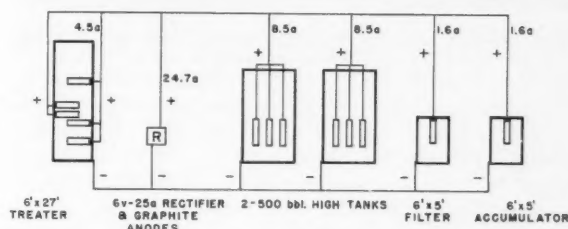


Figure 8—Schematic of cathodic protection system for emulsion treater and water flood equipment.



Figure 9—View of Rectifier 5 and emulsion treater.

Altogether, 206 - 17-pound magnesium anodes were installed. They provided a total drain of 16.5 amperes in addition to the 188 amperes being drained at the 6 rectifiers. Figure 10 shows one stage in the construction of a typical magnesium anode group.

Figure 11 has been prepared to show conditions at the field as they existed on August 14, 1955, at time of final survey. The final survey data are summarized in Table 1.



Figure 10—High potential magnesium anodes ready for horizontal installation in trench.

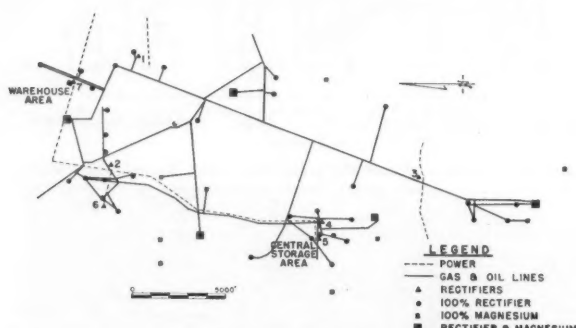


Figure 11—Layout of field showing final status of cathodic protection system.

Post-Installation Testing

Although it did not seem necessary to repeat the expense of a well casing potential log after completion of the cathodic protection system to reaffirm performance of 1.5 amperes drain for a selected well, the opportunity to test two wells by the simple, inexpensive current-potential break method² was not overlooked.

Plans to make such tests were made well in advance of completion of the installation, so that it was possible to set up the following conditions: (1) Downer 2 well, which was originally surveyed by the potential profile method, was provided with a full 2.0 amperes drain in early stages of installation, so that it would have maximum possible time for polarization prior to final testing, and (2) Downer 7 well, an offset to Downer 2, was left disconnected (although provided with an available 1.5 amperes on demand) so that a curve could be obtained for an unpolarized well for purposes of comparison. It was later discovered that only 314 feet of surface pipe had been set for Downer 7, while Downer 2 had a full 1021 feet.

Conventional circuitry for open-circuit potential readings was used in these tests.³ The temporary ground bed for the Downer 2 well consisted of the disconnected gas flow line as in the case of the earlier

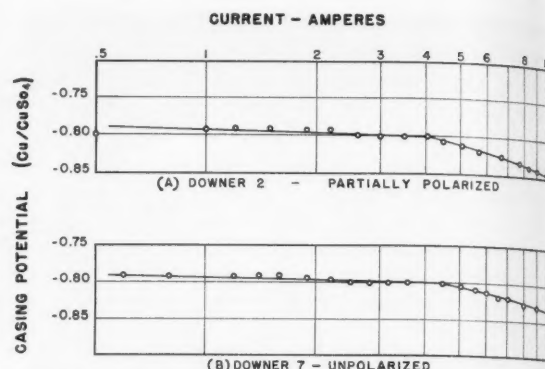


Figure 12—Current versus potential curves for (A) Downer 2 and (B) Downer 7 wells.

TABLE 1—Final Survey Data¹

Well No.	Type of Production	Well-to-Soil Potentials ²	Current Drain (Amps.)	Source of Current ³
1.....	Temp. abandoned		1.60	R
2.....	Gas		1.55	RM
3.....	Oil—Gas	—0.83v	1.80	R
4.....	Oil	—0.87v	1.55	R
5.....	Oil		1.60	R
6.....	Oil		1.95	R
7.....	Oil—Gas	—0.84v	1.50	R
8.....	Oil—Gas		1.50	R
9.....	Oil		1.65	R
10.....	Oil		1.70	R
11.....	Oil		1.55	M
12.....	Gas		1.60	M
13.....	Oil	—0.75v	1.65	R
14.....	Oil—Gas		1.50	RM
15.....	Oil		1.55	M
16.....	Oil		1.75	R
17.....	Oil		1.75	R
18.....	Oil		1.70	R
19.....	Oil		1.65	M
20.....	Oil		1.85	M
21.....	Gas		1.80	RM
22.....	Oil		1.85	R
23.....	Oil		1.50	M
24.....	Gas	—0.99v	1.60	R
25.....	Oil		1.55	R
26.....	Gas—Gas		1.65	R
27.....	Gas—Gas		1.55	R
28.....	Oil		1.55	R
29.....	Oil	—0.89v	1.50	R
30.....	S. W. Injection		1.55	M
31.....	Oil		1.50	R
32.....	Oil		1.55	R
33.....	S. W. Injection	—0.90v	1.50	R
34.....	Gas		1.55	R
35.....	Oil		1.60	R
36.....	Oil		1.55	R
37.....	Oil	—0.84v	1.70	R
38.....	Gas		2.00	R
39.....	S. W. Supply		1.90	R
40.....	Oil		1.50	RM
41.....	Oil—Gas		2.00	R
42.....	Oil		2.00	R
43.....	S. W. Injection		1.50	M
44.....	Oil—Gas	—0.81v	1.50	R
45.....	Oil	—0.74v	1.80	R
46.....	Oil	—0.97v	1.50	M
47.....	Oil		1.80	RM
48.....	Oil	—0.88v	1.90	R

¹ Date: 8-14-55.

² Referred to Cu/Cu SO₄ electrode 75 feet from well head.

³ R = Rectifier

M = Magnesium

RM = Rectifier and Magnesium

casing log tests on this well; for the Downer 7 well its magnesium anode group was used. The copper sulfate reference electrode was located 100 feet from the well head in each case. A vacuum tube voltmeter with 1.6 volt range and a very low resistance contact switch was found most desirable for accurate, duplicable readings.

The curves obtained in these tests are shown in Figure 12. A break is indicated at 4.1 amperes for Downer 2, which had been receiving 2.0 amperes for almost six months, while Downer 7, which had been left without current until tested, shows a break at 4.6 amperes. The difference is in the direction which might have been anticipated (i.e., a lower current requirement indicated for the partially polarized well in spite of its longer surface string). However, under the circumstances this difference (only 0.5 ampere) is not considered highly significant.

What is considered most significant is that this method of testing gives an indicated current requirement more than double that selected from the casing potential logs made during the preliminary survey. It must be remembered that the value of 1.5-2.0 amperes was selected with view to specific performance in the upper casing levels, where corrosion experience had been worst. The current-potential break method presumably looks at more of the casing, if not all 6,000 feet of it in the present case.

In the opinion of the authors, there was no real reason to expect a close correlation in Waskom Field between the results obtained by the current-potential break method and a value of current selected as giving a satisfactory casing potential profile shift down to an arbitrary depth selected on the basis of corrosion experience.

Summary and Conclusion

In order to control external casing corrosion in the shallow formations, a cathodic protection system was designed and installed on a group of 48 wells in the Waskom Field in East Texas. Six selenium rectifiers in conjunction with graphite anode beds, supplemented by 206 high potential magnesium anodes, were used to supply 1.5-2.0 amperes current drain

per well, a requirement based on preliminary casing potential profile studies. Concurrently, cathodic protection was installed in an emulsion treater and water flood equipment using a design current density of 10 milliamperes per square foot.

On the basis of corrosion losses for the first five years of well life, the cathodic protection system for the well casing has a potential return of many times its installation and operating cost, if it approaches 100 percent effectiveness.

Time alone will substantiate selection of 1.5-2.0 amperes drain as optimum for the prevailing conditions. The protective current requirement as indicated by the current-potential break method for two wells in this field was more than double this amount.

Acknowledgment

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La Gloria Oil and Gas Company wishes to acknowledge the assistance provided by Stanolind Oil and Gas Company in making available their casing potential profile tool for use during the preliminary survey.

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**Any discussions of this article not published above
will appear in the December, 1956 issue.**

The Role of Crevices in Decreasing The Passivity of Titanium in Certain Solutions*

By DAVID SCHLAIN and CHARLES B. KENAHAN

Introduction

OTHER WORKERS have reported that titanium is completely resistant to crevice and contact corrosion in sea water and in sodium chloride solutions.^{1,2,3} However, the authors of this report observed that titanium sometimes corrodes in certain acid solutions in which it normally is inert and that this loss of passivity seems to be related to the presence of crevices. The purpose of the investigation reported herein was to verify these observations and to determine some of the conditions under which the existence of a crevice may increase the tendency of titanium to corrode. The results of these experiments are presented as an interesting aspect of the passivity of titanium.

Experimental Work

Sulfuric, hydrochloric, oxalic and formic acids were selected as the chief corrodents. Since the behavior of titanium in ocean water is of special importance, experiments with synthetic ocean water also were included. This solution was prepared according to a formula developed by the ASTM⁴ and had the following composition, in grams per liter: NaCl, 24.53; MgCl \cdot 6H $_2$ O, 11.11; Na $_2$ SO $_4$, 4.09; CaCl $_2$, 1.16; KCl, 0.695; NaHCO $_3$, 0.201; KBr, 0.101; H $_3$ BO $_3$, 0.027; SrCl $_2$ \cdot 6H $_2$ O, 0.042; NaF, 0.003. Titanium specimens used in these experiments were cut from 0.05-inch thick sheet which had been obtained from stock consolidated by arc-melting techniques. This metal contained the following percentages of impurities: Carbon 0.044; nitrogen 0.027; oxygen 0.1; iron 0.13; magnesium 0.013; manganese 0.076; tungsten 0.02 (max.) and silicon 0.04 (max.). The standard experiment used in this investigation involved formation of crevices by placing two titanium specimens or a titanium specimen and a piece of transparent plastic of equal length and width in face-to-face contact. The two halves of the test unit were maintained in contact by means of a small rubber band, a plastic nut and bolt, or a titanium nut and bolt at each end, by one or more spot welds, or by means of a glass holder (Figure 1, A, B, and E to I incl.). The specimen size was 3 x $\frac{1}{4}$, 2 x $\frac{1}{2}$, or 1 x 1-inch and, except when otherwise noted, the specimens used in contact were of equal dimensions and there was complete overlap. The titanium specimens often were bent slightly at the ends and this resulted in a sheet separation at the extreme tips of as much as 0.01-inch. However, over the remainder of the specimens the maximum sheet separations at the time of immersion, in thousandths of an inch, were as follows: Titanium-

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Abstract

Crevice increase the tendency of titanium to corrode in certain solutions in which it normally is made passive by air. This increase in the corrosion rate occurs most consistently in air-saturated 1 N sulfuric and 1.6-1.75 N hydrochloric acid solutions. Corrosion is not confined to crevices but appears to be uniform over the entire surface. An explanation is presented.

3.62

titanium, rubber bands 2 to 3; titanium-plastic, rubber bands 1 to 2; titanium-titanium, titanium nuts and bolts, 2; titanium-titanium, plastic nuts and bolts, 3 to 4; titanium-titanium, 3 spot welds, 2 to 6.

Titanium specimens were given a preliminary polish with wet silicon carbide paper on a mechanical polisher. Before assembly and immersion of the units, the specimens were surfaced by hand with dry 3/0 emery cloth, rubbed with wet pumice, washed with water and dried with acetone. Titanium specimens fastened together with rubber bands or nuts and bolts were weighed separately. Spot-welded specimens were suspended vertically in the vessels and completely immersed in solution. Each vessel contained two or more test units and one or more single specimens.

Experiments in synthetic ocean water were 31 to

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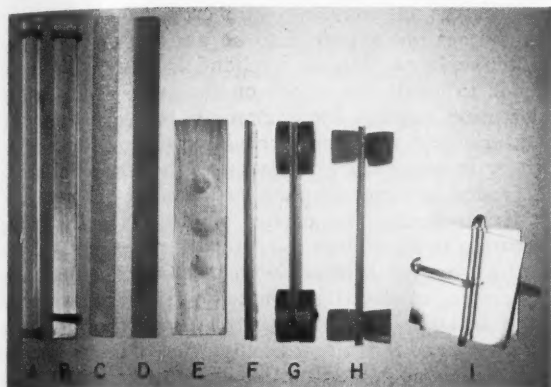


Figure 1—Test units: A—Ti-plastic, rubber bands. B—Ti-Ti, rubber bands. C—Corroded Ti-Ti, inside surface. D—Corroded Ti-Ti, outside surface. E—Ti-Ti, spot welds, face view. F—Ti-Ti, spot welds, side view. G—Ti-Ti, Ti nuts and bolts. H—Ti-Ti, plastic nuts and bolts. I—Ti-Ti, glass holder.

63 days long and were carried out at 35 C in loosely covered vessels without forced aeration. The test units consisted of two titanium specimens or a titanium specimen and a piece of plastic fastened together with a spot weld or with rubber bands. The results show that titanium is not susceptible to crevice or contact corrosion in this environment. Thirteen units containing crevices and six single specimens all were inert; that is, they had corrosion rates of 0.0 mpy (mil penetration per year).

In acid solutions, experiments were carried out in stoppered bottles and the solutions were saturated with air (Figure 2). Air was passed through the solution for about one hour before the specimen was immersed and continuously throughout the experiment. Air-flow rates were about 50 ml/min and the volume of solution was 500 ml. These experiments usually were 15 days long and, except for those in formic acid, were carried out at 35 C. The total titanium specimen area in each test unit was used in converting weight-losses to corrosion rates in mpy. Each corrosion value given represents the average corrosion rate for the total metallic surface of the unit.

Data in Table 1 show that pairs of titanium specimens in face-to-face contact in 1 N sulfuric acid solution with a flow of air corroded much more rapidly than single specimens. Titanium in contact with plastic also was active in this environment. Similar results were obtained when two titanium specimens were fastened together with spot welds, titanium nuts and bolts, or plastic nuts and bolts. The effect of variations in sheet separation was determined with titanium-titanium units fastened with plastic nuts and bolts. Corrosion rates were highest when the maximum sheet separation was 0.003-0.004-inch through the center and 0.01-inch at the extreme tips (Table 2). Lower corrosion rates were obtained when the maximum sheet separation was increased to 0.006-0.008-inch or decreased to 0.001-0.002-inch. The amount of overlap appeared to have a significant effect on the tendency for titanium to corrode. Pairs of titanium specimens spot-welded together with a 1½-inch overlap instead of complete overlap corroded

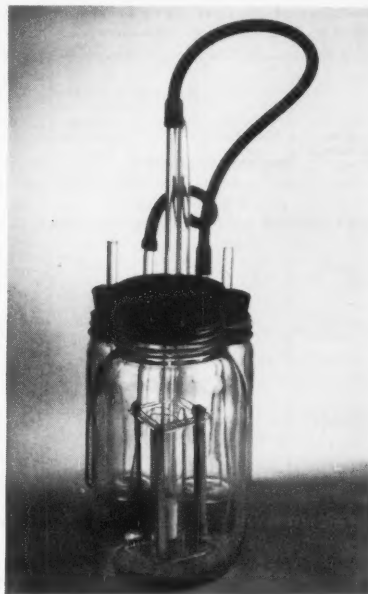


Figure 2—Apparatus used in corrosion experiments.

less rapidly (Table 3). When the overlap was decreased to one inch, there was still less corrosion. Since the specimens used in this work were not perfectly flat, changes in the amount of overlap probably changed the shape as well as the area of the crevice.

Existence of crevices or contact points generally had much less effect on the corrosion rates of titanium in 0.75 N and 0.50 N sulfuric acid solutions with a flow of air than it did in 1 N sulfuric acid solution (Table 4).

Single specimens of titanium are passive at 35 C in 1.6 N and 1.75 N hydrochloric acid solutions with a flow of air. However, as illustrated by the data in Table 1, titanium in contact with other titanium specimens or with plastic was active in over 70 percent of the cases. Crevice corrosion did not occur in either 1 N or 2 N hydrochloric acid solutions with a flow of air. In 1 N acid, neither the specimen pairs nor the single specimens were active (0.0 mpy). In 2 N acid, pairs of titanium specimens, titanium in contact with plastic and single titanium specimens all were active (23 to 28 mpy).

Crevices or contact areas caused corrosion much less frequently in 1 and 9 percent oxalic acid than in mineral acids. Only about 25 percent of the test units were active (Table 1). In 50 percent formic acid with a flow of air at 100 C, only 2 of 16 replicates were active. However, the active specimens corroded very rapidly. The elastic properties of the rubber bands were affected greatly in this environment and therefore did not hold the specimens properly in contact for the entire experimental period. No test units were active in this solution at 60 C.

In all of these experiments, when one specimen of a titanium pair corroded the other also did and the corrosion rates for the two specimens were always quite similar. Furthermore, in experiments with either titanium-titanium or titanium-plastic units cor-

TABLE 1—Effect of Crevices Upon Corrosion Resistance of Titanium in Acid Solutions with Flow of Air, 15 Days

Test unit; size, inches; fastening; arrangement	Total Number of Replicates	Replicates, Active		Replicates, Passive	
		Number	Average Corrosion Rate, mpy	Number	Average Corrosion Rate, mpy
1 N H ₂ SO ₄ , 35 C (Average corrosion rate for 32 single specimens 1.2 mpy)					
Ti-Ti, 3 x 1/4, rubber bands, complete overlap	7	7	19.5	0	....
Ti-Ti, 3 x 1/4, rubber bands, 2 1/2" overlap	3	3	11.3	0	....
Ti-Ti, 2 x 1/2, 3 spot welds, complete overlap	3 ¹	3	15.9	0	....
Ti-Ti, 2 x 1/4, titanium nuts and bolts, complete overlap	4	4	6.9	0	....
Ti-Ti, 2 x 1/2, plastic nuts and bolts, complete overlap	4	4	12.9	0	....
Ti-plastic, 3 x 1/4, rubber bands, complete overlap	5 ²	5	21.9	0	....
1.6 N and 1.75 N HCl, 35 C (Average corrosion rate for 9 single specimens 0.12 mpy)					
Ti-Ti, 3 x 1/4, rubber bands, complete overlap	17	13	20.1	4	0.13
Ti-Ti, 1 x 1, in contact in glass holder	4	4	10.0 ³	0	....
Ti-plastic, 3 x 1/4, rubber bands, complete overlap	11	6	16.1	5	0.12
1 percent Oxalic Acid, 35 C (Average corrosion rate for 5 single specimens 0.05 mpy)					
Ti-Ti, 3 x 1/4, rubber bands complete overlap	12	4	4.7	8	0.07
Ti-plastic, 3 x 1/4, rubber bands, complete overlap	8	1	1.5	7	0.10
9 percent Oxalic Acid, 35 C (Average corrosion rate for 3 single specimens 0.40 mpy)					
Ti-Ti, 3 x 1/4, rubber bands, complete overlap	10	3	28.5	7	0.55
Ti-plastic, 3 x 1/4, rubber bands, complete overlap	6	1	31.6	5	0.40
50 percent Formic Acid, 60 C (Average corrosion rate for 2 single specimens 0.00 mpy)					
Ti-Ti, 3 x 1/4, rubber bands, complete overlap	8	0	....	8	0.04
50 percent Formic Acid, 100 C (Average corrosion rate for 4 single specimens 0.00 mpy)					
Ti-Ti, 3 x 1/4, rubber bands, complete overlap ⁴	16	2	116.4	14	0.00

¹ Two additional replicates immersed for 3.9 days, average corrosion rate 24.6 mpy.
² One additional replicate immersed for 1 day, average corrosion rate 15.6 mpy.

³ One additional replicate immersed for 5.9 days, average corrosion rate 29.5 mpy.
⁴ One additional replicate immersed for 1 day, average corrosion rate 29.0 mpy.

⁵ Experiment was 20 days long.

⁶ The formic acid destroyed the elasticity of the rubber bands and therefore the specimens were not in proper contact after the first day or two of the experiment.

rosion was not confined to the crevice or to the areas in contact but appeared to be uniform over the metallic surfaces (Figure 1, C and D). Attempts were made to locate the points on the specimen at which corrosion started by immersing test units in 1 N sulfuric acid for short periods of time. However, in every instance the specimens were either uniformly corroded or were completely unchanged in appearance.

Experiments were carried out in 1 N sulfuric acid solution to determine if a titanium specimen corroding in air-free solution will cause another titanium specimen, in electrical contact with it and immersed in solution saturated with air, to corrode. The apparatus used for this work consisted of two stoppered bottles connected with a bridge. The bottles and the bridge all contained 1 N sulfuric acid, but one bottle was aerated with air and the other with helium. Each experiment involved four identical titanium specimens, two in each specimen bottle. The specimens were inserted through slits in small rubber stoppers which fitted tightly in holes in the larger stopper. These formed gastight seals, yet permitted external connections. A couple was formed by connecting one specimen in each bottle through a 1-ohm resistance (± 1 percent); the other two specimens were not coupled. Galvanic currents flowing through the couple were determined by measuring the voltage drops across the resistance with a potentiometer and applying Ohm's law. Galvanic corrosion rates were calculated from average galvanic currents by applying Faraday's law. The weight losses of coupled and uncoupled specimens were determined. The electrode potentials of the specimens were measured with a potentiometer, a saturated calomel electrode and a saturated potassium chloride bridge.

In these experiments titanium, ordinarily resistant to air-saturated 1 N sulfuric acid, corroded rapidly in such a solution as a result of electrical contact with titanium specimens corroding in air-free solution (Table 5). In a similar experiment with synthetic ocean water, using specimens with equal areas, all four titanium specimens were inert and there was no galvanic current.

TABLE 2—Effect of Sheet Separation, 1 N Sulfuric Acid Solution With Flow of Air, 35C, 15 Days
(Test unit: Ti-Ti, 2 x 1/2-Inch, plastic nuts and bolts, complete overlap)

Sheet Separation, Inch	Total Number of Replicates	Replicates, Active		Replicates, Passive	
		Number	Average Corrosion Rate, mpy	Number	Average Corrosion Rate, mpy
0.006—0.008	4	4	6.9	0	....
0.003—0.004	4	4	12.9	0	....
0.001—0.002	9	0	....	9	1.5

TABLE 3—Effect of Overlap, 1 N Sulfuric Acid Solution With Flow of Air, 35C, 15 Days
(Test unit: Ti-Ti, 2 x 1/2-Inch, spot weld)

Overlap, Inches	Total Number of Replicates	Replicates, Active		Replicates, Passive	
		Number	Average Corrosion Rate, mpy	Number	Average Corrosion Rate, mpy
2 (complete)	3	3	15.9	0	....
1 1/2	3	3	4.2	0	....
1	12	5	3.1	7	1.3

The large increase in the corrosion rate of titanium specimens immersed in air-saturated 1 N sulfuric acid and connected to titanium specimens in air-free solution does not represent galvanic corrosion. Both the direction of current flow and the relative electrode potentials of the two single specimens show that the specimen in air-free solution is the anodic (corroding) member of the couple. The explanation suggested for this increase in the corrosion rate is that the passage of current through the couple is accompanied by a flow of electrons to the surface of the titanium specimen in the air-saturated solution (cathodic member of the couple). At least some of these electrons are consumed in the reduction of hydrogen ions to active hydrogen. The protective oxide film is destroyed as a result of the reducing atmosphere on the titanium surface and corrosion takes place. Similar effects have been observed in experiments with stainless steel-aluminum and titanium-aluminum alloy couples.^{5,6} This phenomenon does not occur in synthetic ocean water because titanium is inert in this solution even when air-free.

Figure 3 includes the time-electrode potential curve for a single titanium specimen corroding in air-free 1 N sulfuric acid solution (corrosion rate 12.8 mpy). The corresponding curve for a single titanium specimen in 1 N sulfuric acid saturated with air shows that the presence of air causes titanium to acquire a more noble potential (average corrosion rate for 20 days, 0.2 mpy). All of the weight lost by this specimen was probably lost during the brief period shortly after immersion when the electrode potential was quite negative. Experience has shown that titanium corroding in an acid solution has an overall electrode potential of about -0.55 volt or less noble (on the saturated calomel electrode scale). Time-electrode potential curves for titanium-titanium and titanium-plastic test units show longer periods of activity and higher average corrosion rates (Ti-Ti 15.6 mpy; Ti-plastic 34.4 mpy). This was also the case in experiments with separated couples. When the ratio of specimen areas was 48 to 1, the period of activity was shorter than it was when the ratio was 1 to 1 and the average corrosion rate of the coupled specimen immersed in air was lower (Table 5).

Discussion

A single titanium specimen without crevices immersed in 1 N sulfuric acid with a flow of air corrodes rapidly for a brief period soon after immersion. If an ample supply of air reaches all points on the metal surface, a stable film quickly forms and corrosion stops. When a test unit containing suitable crevices is immersed in this solution the initial period of corrosion lasts longer because air cannot reach the titanium surfaces in the crevices in quantities sufficient to passivate them. The inner and outer surfaces of each titanium specimen act in a manner similar to the members of the separated galvanic couple described above. The corrosion taking place on the inner surfaces, while relatively small, causes a sufficiently large flow of electrons to the outer surfaces to eventually destroy the protective oxide film and

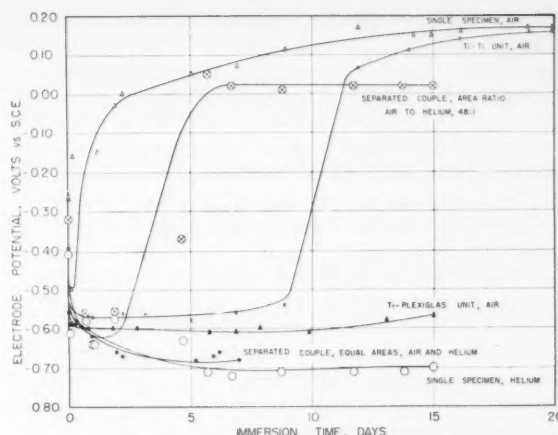


Figure 3—Time-potential curves, 1 N sulfuric acid, 35 C.

TABLE 4—Effect of Sulfuric Acid Concentration, Flow of Air, 35C, 15 Days

(Test unit: 3 x 1/4-inch, rubber bands, complete overlap)

Test Unit	Total Number of Replicates	Replicates, Active		Replicates, Passive	
		Number	Average Corrosion Rate, mpy	Number	Average Corrosion Rate, mpy
1 N					
(Average corrosion rate for 32 single specimens 1.2 mpy)					
Ti-Ti.....	7	7	19.5	0	....
Ti-plastic.....	5	5	21.9	0	....
0.75 N					
(Average corrosion rate for 3 single specimens 0.4 mpy)					
Ti-Ti.....	3	2	2.1	1	0.7
Ti-plastic.....	1	1	25.6	0	....
0.50 N					
(Average corrosion rate for 3 single specimens 0.2 mpy)					
Ti-Ti.....	3	1	1.9	2	0.2
Ti-plastic.....	1	1	1.5	0	....

TABLE 5—Separated Galvanic Couples, Ti-Ti in Air-saturated And Air-Free 1 N Sulfuric Acid Solutions, 35C.

Ratio of Specimen Areas, Saturated with Air: Air-free	Anodic Specimen	Galvanic Corrosion, mpy (Calculated from Current)	Corrosion Rate, mpy (Based on Weight Loss)			
			Saturated with Air		Air-free	
			Coupled	Uncoupled	Coupled	Uncoupled
1:1	Air-free	1.3	31.4	0.4	17.0	20.0
48:1	Air-free	1	8.3	1.6	6.8	12.8

¹ Galvanic current was too small to measure accurately.

bring about general corrosion over the entire specimen surface.

It has been shown that sheet separation is critical. Crevices must have the proper characteristics. Possibly, when the sheets are too close together the surfaces in the crevice are not wetted or, if they are wetted initially, the flow of solution is so restricted that the acid content of the solution is depleted before the protective film is destroyed. When the sheets are too far apart diffusion of air is rapid enough to passivate the surfaces of the crevices. Changes in the

size or shape of the titanium sheets might be expected to change the critical values of the sheet separation. The characteristics of the contacts and of the crevices formed in a titanium-titanium unit undoubtedly differ from those formed in a titanium-plastic unit. Different methods of fastening produce additional differences. Eventually, anodic polarization may cause corrosion to stop. Small differences in the characteristics of the crevice also may be important in determining if and when corrosion stops. One might explain the behavior of test units in 1.6 N and 1.75 N hydrochloric acid, 1 and 9 percent oxalic acid, and 50 percent formic acid at 100 C in the same manner. In each instance titanium is passive in an air-saturated solution and active in air-free solution. Loss of passivity as a result of crevice action occurs less readily in the more dilute sulfuric and hydrochloric acids and in the oxalic and formic acid solutions because the protective film is more difficult to destroy in these weaker acids.

Conclusions

1. Crevices cause titanium to corrode in certain acid solutions in which it is ordinarily quite inert. Corrosion is not confined to crevices but quickly becomes general.

2. Crevices have this effect in solutions in which titanium owes its passivity to the presence of air. The phenomenon occurs consistently in air-saturated 1 N sulfuric and 1.6 N and 1.75 N hydrochloric acids at 35 C; it occurs less readily in less concentrated

sulfuric acid and hydrochloric acid, in 1 and 9 percent oxalic acid solutions at 35 C and in 50 percent formic acid solution at 100 C. However, the nature of the crevice is critical and it is conceivable that minor changes in it might cause corrosion in the weaker acids.

3. A possible explanation for the effect of crevices on passivity is that corrosion in the air-starved crevices (anodic surfaces) results in the flow of electrons to and the evolution of active hydrogen on the remainder of the titanium specimen (cathodic surfaces). In this reducing atmosphere the protective oxide film is destroyed and general corrosion follows.

4. Titanium does not corrode in synthetic ocean water even when crevices are present.

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**Any discussions of this article not published above
will appear in the December, 1956 issue.**



TECHNICAL COMMITTEE ACTIVITIES

Grain Structure Key to Life of Oil Well Tubing

SOUTH CENTRAL REGION TECHNICAL PROGRAM MEETINGS (Tentative)

Gunter Hotel, San Antonio, Texas Oct. 23-26, 1956

Tuesday, Oct. 23

AM	T-1 9-11:30					
PM	T-1 1:30-5	T-2E 1:30-4:30	T-6B 1:30-4:30	T-2D 1:30-4:30	T-3G 2:00-4:30	T-5D 1:30-4:30

Wednesday, Oct. 24

AM	T-1K 8:30-11:30	T-2J	T-6E 8:30-11:30	T-5C-1 8:30-11:30	T-2C 8:30-11:30	T-1J 8:30-11:30	T-6A 8:30-11:30
PM	T-1G 2:00-3:30 T-1F 3:30-5:00	T-2K 2:00-4:30	T-5E 2:00-4:30	T-6D 2:00-4:30	South Central Region Trustees Luncheon 12:15	T-7D 2:00-4:30	T-1M 2:00-4:30

Thursday, Oct. 25

AM				T-1H 9:00-11:30	Author's Breakfast 7:30-8:30	Pipe Line Industry Symposium 8:30-11:30	Elevated & High Temperature Symposium 8:30-11:30
PM				T-5B-2 2:00-5:00		Oil & Gas Production Symposium 2:00-5:00	Utilities Industry Symposium 2:00-5:00

Friday, Oct. 26

AM			T-1D 8:30-10:00 T-1B 10:00-11:30	T-5B-2 8:30-11:30	Author's Breakfast 7:30-8:30	Cathodic Protection Symposium 8:30-11:30	Transportation Industry Symposium 8:30-11:30
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API Thread Compound Passes Galvanic Tests

Good Results Reported Squeezing Inhibitors Into Salt Water Wells

Good results with squeezing inhibitors into wells producing up to 10,000 barrels of salt water were reported by a member of T-1 at the October meeting of the committee in Houston. No plugging of water sand was reported.

Another member said stick and liquid inhibitors were being successfully applied in wells with persistence from 6 weeks to 6 months. Cost was estimated at about 5 mills per barrel of oil produced.

Several means of getting inhibitors into the bottom of wells were reported. Wire tools were mentioned as was successful use of another device that delivered the inhibitor to the bottom of the well, released it and returned to the surface.

Five regional NACE meetings will be held during the fall of 1956.

Tests with American Petroleum Institute's high pressure thread compound in 5 percent salt water under a little better than one atmosphere pressure of bubbling carbon dioxide show the compound to have no bad galvanic effects. Some concern had been expressed over the possibility that the copper content of the compound might produce galvanic corrosion under some oilwell conditions.

Results of the 6-month test in the salt water and carbon dioxide were reported at a meeting of T-1 at the Shamrock-Hilton Hotel in October during the South Central Region's meeting there. Some pitting was obtained in some of the other laboratory tests. Difficulties with the compound could occur, it was pointed out, under some oil well conditions.

The possibility that an inhibitor could be incorporated in the compound was discussed also.

More than 1000 references are indexed in the Alphabetical Subject Index to Volume 11, Corrosion.

22 Rockwell Called Division Between Good, Bad Service

More attention must be paid to grain structure and less to the different grades of steel used for oil well tubing. This suggestion was made during a discussion of materials suitable for tubing at a session of T-1 at the Shamrock-Hilton Hotel during the South Central Region meeting last October.

Discussion revolved around experience with 9 percent nickel tubing and its service life in wells. One West Coast member said his company estimated tubing to last five years and that no tubing over three years old was re-run. Stress corrosion cracking was along longitudinal stress lines in some environments.

All failed specimens tested by this company showed hardness in excess of 22 Rockwell. This same member asked T-1 members to send samples of burst tubing to him for examination so statistical analyses could be prepared.

Laboratory tests have shown 9 percent nickel steel to pit violently in water with chlorides, it was asserted. One member said that any well expected to produce salt water probably should not be run with 9 percent material.

Good reports on 9 percent nickel sucker rods in West Kansas were heard. Some rods had been so long in service in wells there that they were lost track of. Another member said his company had 9 percent nickel sucker rods to fail in three to four months in sulfide wells. Best solution to sucker rod corrosion, in his experience, he said was to buy the cheapest rods available and protect them with inhibitors.

Casing Shows No Damage From Cathodic Protection

Casing pulled from four East Texas field wells which had been under cathodic protection for 11 to 12 months showed no damage at the base of the surface pipe. This was reported to T-1 at its October, 1955 meeting at the Shamrock-Hilton Hotel in Houston. A calcareous scale was found on all casings.

The wells had been kept under drainage of 0.5, 1.5, 5 and 10 amperes during the test period. The wells were completed in 1931-33-37.

Railroad News Letter Out

The May, 1956 issue of Railroad Corrosion News Letter includes articles on metallizing, galvanic corrosion coatings, cathodic protection, nickel plating and metal sheathing for pilings. The publication is a function of Technical Committee 3-E on Corrosion Control in the Transportation Industries.

Cost Data on Railroad High Performance Cars Sought by Unit T-3E

Experience and cost data on the construction of railway cars intended to have high resistance to corrosion are being sought by Unit Committee T-3E on Railroads. This matter was discussed at an Annapolis, Md. meeting of the group in April and at a meeting during the NACE New York Conference in March.

The aim would be to collect information which would indicate the economics of methods relatively expensive in short view when extended into longer trouble free car life.

One member reported at the Annapo-

lis session that his company found that while a low-alloy steel has proved satisfactory his road was returning to open hearth steel because of its lower price. A coating was recommended as a means of preventing corrosion in covered hopper cars in potash and salt service.

At the March meeting it was suggested that specifications for painting be modified to stipulate mil thickness rather than coats and that a minimum of four mils be carried on cars in Southern service while three be set as a minimum for cars used in the North. Geographical considerations should be weighed in selecting car colors, it was suggested also.

Topical Indices to the material published in the Technical Section of Corrosion are published annually in the December issue.

Widespread Application of Cathodic Protection to Oil Well Casings Reported

Widespread application of cathodic protection to the casings of oil wells in Western Kansas, East Texas and California was reported at a meeting of NACE Technical Unit Committee T-1H on Oil String Casing Corrosion. The meeting was held during the NACE Twelfth Annual Conference in New York in March.

A statistical study is under way on installation of cathodic protection on about half the wells of a 350-well block in the East Texas field. Another company reported plans completed for protection of about 200 wells in the East Texas field during a 2-year period, using 24-volt, 12-ampere rectifiers. Another member reported on work done in protecting cathodically wells in the Williston Basin area.

Corrosion losses in a California field of \$200,000 a year for the past five years were reported by another member. Some 22 wells in this field presently are under protection.

Considerable attention was given to the problems involved in handling interference currents when protecting oil well casings cathodically. Means of determining the efficiency of systems by both surface potential measurements and casing potential logs were described.

More Concrete Gains Cited By TP Committee Head

Of the thirty technical reports published by the National Association of Corrosion Engineers since reorganization, of its technical committees along industrial lines, 15 have been published during the first six months of 1956. Only twelve reports were published by NACE during the 8 years preceding reorganization of the technical committees. These facts are among many cited by C. P. Larrabee, United States Steel Corp., Monroeville, Pa., chairman of the Technical Practices Committee in his report to the president of NACE.

The report also showed participation by 826 NACE members representing 474 different companies as of June 1, a gain in both categories over the number reported in September, 1954. Of the companies represented 202 are corporate members. Forty-three companies are represented on committees by non-member technical advisers.

Mr. Larrabee pointed to the encouraging growth of task groups among the committees. These working groups help break problems into smaller, workable parts and give wider opportunity for participation in committee work, he said.

Caliper Surveys Preferred To Test Inhibitors' Merits

Caliper surveys seem to be preferred means of determining effectiveness of inhibition of water dependent sweet oil wells. This was reported to members of T-1 meeting during the South Central Region's 1955 meeting in Houston.

Caliper surveys were reported used more frequently than coupon tests, hydrogen evaluation, drop size ratio, film resistance and other means.

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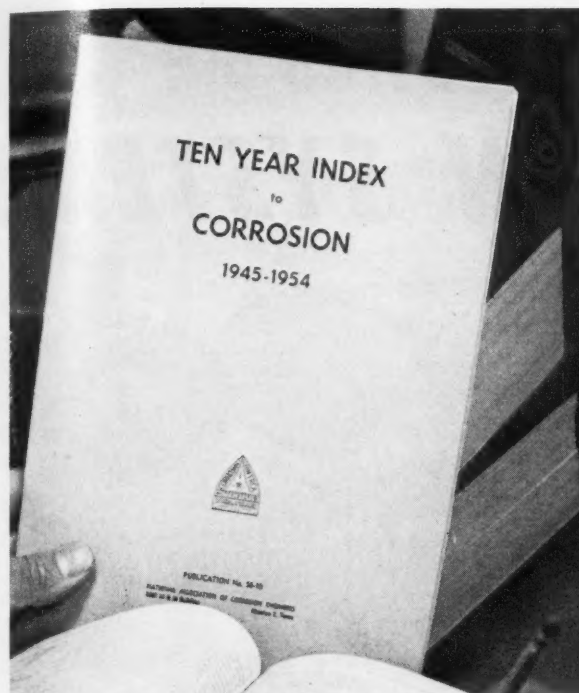
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NACE NEWS

Four Trips Planned For Detroit Meeting

Arrangements have been made for four plant trips during the North Central Region meeting at Detroit, November 15-16. Projected trips include visits to Wyandotte Chemicals Corp., Chrysler Corp., International Salt Company (shaft type mine) and Hiram Walker Distillery (Canada). Section officials recommend a certificate of birth or proof of citizenship for those planning to go to Canada.

Planned for ladies attending the meeting is a trip to the J. L. Hudson Company's Northland, a large shopping center.

Section members working on the program point out Detroit has a wide variety of after hours entertainment and that Canada is a 10 cent bus ride away, via the tunnel under the Detroit River. Excellent food and good hotel accommodations are available.

Broad Range of Topics Set for Shreveport Course

The program for the Sixth Annual Corrosion Control Short Course sponsored by Shreveport Section at Centenary College, Shreveport indicates attention will be given to inhibition of oil wells, plastic materials, corrosion problems in processing plants as well as underground corrosion and cathodic protection. Field trips scheduled include a demonstration of chemical inhibitor treatment of oil and gas wells and a rectifier installation for cathodic protection of a pipeline.

The advance program has been given as follows:

Thursday, September 20—Registration, fundamentals, corrosion problems in processing plants, oil and gas well corrosion control, cathodic protection instruments, well casing cathodic protection, cathodic protection, survey design, cathodic protection maintenance.

Friday, September 21—Atmospheric corrosion control, plastic materials of construction, corrosion control in distribution systems, underground protective coatings; field trips: Chemical inhibitor treatment of oil and gas wells, cathodic protection rectifier installation on pipeline.

The \$10 registration fee includes two noon meals, fellowship hour and banquet. Classes will be held in the air conditioned Science Building on the Centenary College campus.

Northeast Region Sessions Scheduled on New Alloys, Ceramics, Plastic Materials

Television Stars to Entertain at Lunch



Ginny and Dave Stephens (top) WCAU Philadelphia television performers and Ed Harvey (right), master of ceremonies for television programs will be heard at the Tuesday, October 16 luncheon during Northcentral Region's meeting at the Drake Hotel, Philadelphia. Mr. and Mrs. Stephens are on the "Here's Harvey" show five days a week. Ed Harvey is master of ceremonies for the show.

San Francisco Hears Eldredge on Statistics

Dr. G. G. Eldredge, Shell Development Company, Emeryville, California spoke on Statistics of Corrosion Pitting at the June 20 meeting of San Francisco Bay Area Section. The meeting at Berkeley was attended by approximately 35 members and guests. Dr. Eldredge spoke on the application of extreme value statistics to the prediction of the expectation of deep pits and perforations, particularly in oil well tubing. A discussion period followed the formal presentation.

Because of the current short supply of nickel and the resulting focus of attention on low-nickel alloys, two of the technical symposia to be held at the Northeast Region's October 15-17 meeting in Philadelphia are especially important. One symposium, on new alloys and ceramics, gives valuable current information on these materials, while significant data on synthetic elastomers will be covered in a symposium on plastics.

Three papers scheduled for the Symposium on New Alloys and Ceramics will cover: Corrosion Resistance of Low Nickel and Nickel-less Stainless Steels, Fabrication of Titanium and Recent Developments in Ceramics for Application in Corrosive Atmospheres.

The symposium on plastics will emphasize the possibility of substituting elastomeric materials for metals.

Also scheduled are papers on protective coatings and statistical methods.

Other Features

Among other features of the meeting will be: A Fellowship Hour on Tuesday, October 16, WCAU entertainers Ed Harvey and Pete Boyle at Tuesday and Wednesday luncheons.

Two busy days are in store for ladies attending. A tour of points of historical interest will be available as will tickets for attendance at Hi-Neighbor and Cinderella Weekend radio and television shows. A fashion show at Lord and Taylor's will be offered.

Technical Committees to Meet

First day of the meeting, October 15, has been reserved for technical committees. Scheduled so far are sessions of T-2K on Prefabricated Plastic Film for Pipe Line Coatings; T-4F on Materials Selection for Corrosion Mitigation in the Utility Industry, T-4F-1 on Materials Selection for the Water Industry and T-7A North East Region Corrosion Coordinating Committee.

These were reported erroneously in a headline in July CORROSION to be scheduled for a Detroit meeting.

All sessions will be at the Drake Hotel.

Telephone Corrosion Is Topic at Miami Meeting

Approximately 25 members and guests attended the May 18 meeting of the Miami Section at which D. T. Rosselle spoke on corrosion problems encountered in Southern Bell's Southeastern District. The section also voted to hold six meetings yearly, the next scheduled July 20.

It was announced also an attempt is being made by H. B. Sasman of Sasman Engineering Company and Sigmund Miller of the University of Miami Marine Laboratories to arrange a short course on corrosion.

More than 4000 entries are included in the 10-Year Index to Corrosion's Technical Section.

HALF-YEAR MEMBERSHIPS AVAILABLE

Active membership in the National Association of Corrosion Engineers for the six months July-December, 1957 inclusive is available at \$6. Membership includes copies of CORROSION and all other privileges. Applications may be obtained on request from A. B. Campbell, Executive Secretary, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

St. Louis Conference Officials



Effinger



Fenner



Gribble



Meyer



Ries

St. Louis Section and is active in technical committee work. He has been a NACE member since 1950.

OFFICERS WORKING on 1957 NACE Conference matters are: Top, left to right R. T. Effinger, Shell Oil Co., Houston, Technical Program Committee chairman, has 20 years of corrosion experience. He joined NACE in 1946 while at Shell's Martinez Refinery. Otto H. Fenner, Monsanto Chemical Co., St. Louis, General Conference Committee chairman, has been with Monsanto since 1934. He organized Greater St. Louis Section, has been active in NACE affairs otherwise. Charles G. Gribble, Jr., Metal Goods Corp., Houston, Exhibits Committee co-chairman, has been a NACE member since 1948 and has been active in Houston Section and South Central Region affairs. He is branch manager for his company in Houston. Walter B. Meyer, St. Louis Metallizing Co., St. Louis, Exhibits Committee co-chairman, has been active in the metallizing field since 1935. He is president of his company. (left) William J. Ries, Tretolite Co., St. Louis, Local Arrangements Committee chairman has been an officer of Greater



OFFICERS OF CENTRAL NEW YORK SECTION are shown here at the May 18 meeting of the section. They are, left to right, Jack Yates, Niagara Mohawk Power Corp., secretary-treasurer; F. C. Jelen, Solvay Process Division, Allied Chemical and Dye Corp., chairman; W. Leonard Smart, Carbolo Chemical Co., Natural Bridge, N. Y., featured speaker; Andrew Kellogg, Niagara Mohawk Power Corp., Syracuse, retiring chairman and Orrin Broberg, Lamson Corp., vice-chairman.

Mechanism of Paint Performance Is Central New York Section Topic

Fatty acid amines applied to ferrous metal surfaces apparently are adsorbed preferentially onto the metal surface to form a film resistant to moisture, W. Leonard Smart, Carbolo Chemical Co., Natural Bridge, N. Y. told members of Central New York Section. He spoke at the section's May 18 meeting. Mr. Smart spoke on surface preparation, rheological factors affecting paint performance, the theory of rust formation in voids underneath paint surfaces, differences in wetting power between oleoresinous vehicles and quick drying synthetic resins and other aspects of paint application and performance.

During the second annual business meeting of the Central New York Section at the Pine Tree Point Club, June 23, 24 at Alexandria Bay, New York, the following officers were installed for the coming year: F. C. Jelen, chairman, Solvay Process Division of Allied Chemical & Dye Corporation; Orrin Broberg, Lamson Corporation, vice-chairman and Jack Yates, Niagara Mohawk Power Corporation, secretary-treasurer.

Kellogg Accepts Post for 1957 Syracuse Conference

Andrew Kellogg, Niagara Mohawk Power Corp. Syracuse has accepted the post of general chairman of the Northeast Region Corrosion Control Conference to be held May 20-22, 1957 at Syracuse University.

South Central Region Officers Nominated



Barrett



Spalding



Caldwell



Levert

Nominations for offices in South Central Region, National Association of Corrosion Engineers have been made as follows by the nominating committee:

Jack P. Barrett, for chairman. Mr. Barrett, regional vice-chairman, is past chairman of Tulsa Section. He is now Research Group Supervisor, Stanolind Oil and Gas Co., Tulsa. Active in NACE since 1947, he is a member of several technical committees and has published papers on coatings, cathodic protection and inhibitors.

J. C. Spalding, Jr., for vice-chairman. Presently secretary-treasurer, he is Section Supervisor of Chemical and Equipment Engineering, Petroleum Engineering Branch, Operating Dept., Southwest Division, Sun Oil Co., Dallas. Active in NACE since 1947, he has been chairman of North Texas Section, Chairman of T-1K, has published papers on inhibitors and corrosion control on oil production equipment and has been active otherwise in the association.

J. A. Caldwell, for secretary-treasurer. Since 1945 Mr. Caldwell has been employed in the Production Research Division of the Humble Oil and Refining Co., Houston where he is now Senior Research Engineer. He has published several papers on corrosion in oil production operations. Active on several committees, he is past chairman of Houston Section and presently assistant secretary-treasurer of the region.

William F. Levert, for assistant secretary-treasurer. A graduate of Louisiana Polytechnic Institute with a BS in mechanical-electrical engineering, 1938, he has been in the Corrosion Engineering Department of United Gas Pipe Line Co., Shreveport for the past 15 years. He has been an active NACE member since the association was first organized. A past chairman of and presently trustee of Shreveport Section, he is now Corrosion Engineer for United Gas Pipe Line Co., Shreveport.



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Corrosion Course Begins at Houston University Sept. 18

University of Houston opens September 18 a one-semester course on corrosion. The 3-hour course, with sessions on Tuesday and Thursday nights on the main campus, may be taken for credit or audit.

Four sections of 8 to 10 lectures each are given on electrochemical theory, metallurgy, protective coatings and design, and cathodic protection. Benjamin F. Davis, Jr., Aquaness Div., Atlas Powder Co., is instructor in theory. W. N. Lyons, Hughes Tool Co., metallurgy; Talmage Heitman, Jr., United Gas Corp., cathodic protection and H. E.

Waldrip, Gulf Oil Corp., protective coatings, inhibition and design.

Registration is on September 10-12, main campus.

LaJolla Course Errata

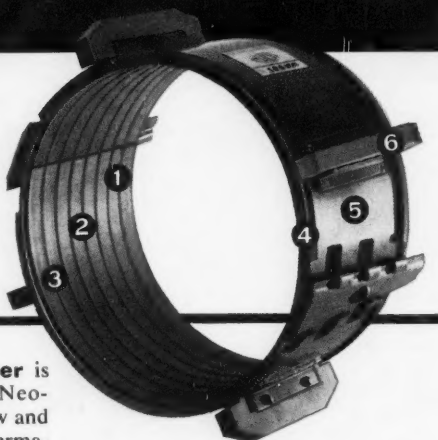
Titles and authors of two items presented during the LaJolla Marine Corrosion and Fouling Problems Course as reported on Page 86 of June CORROSION were garbled. Correct version is:

Principles and Practice of Cathodic Protection, Harry J. Keeling, Consulting Engineer, Los Angeles.

Use of Half-Cell Reference Electrodes in Corrosion Measurements, R. E. Hall, Research Engineers, Union Oil Co., Brea, Cal.

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3 Multiple longitudinal ribs* act as a gripping tread, prevent slippage during installation and frictional displacement of coating (cold flow) after installation.

4 Extruded liner lips prevent movement of liner on heavy gauge steel band.

5 Rugged construction to withstand installation shock loads and post-installation static load. Plico Spacer bands are cold-formed of 12-gauge steel in 12" diameter and larger, and of 14-gauge steel in 10" diameter and smaller. Band widths are 6", 8" and 12".

6 Skids of heavy-duty, high-density laminated Micarta, accurately spaced and securely fastened to the band, provide high dielectric strength and abrasion resistance and assure the extra safety factor of double insulation.



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*Patents Pending



NATIONAL, REGIONAL MEETINGS and SHORT COURSES

1956

Oct. 15-17—Northeast Regional Meeting, Philadelphia.

Oct. 23-26—South Central Region, Gunter Hotel, San Antonio, Texas.

Nov. 8-9—Southeast Region Fall Meeting, Charlotte, N. C.

Nov. 15-16—North Central Region Meeting, Detroit, Mich.

1957

Mar. 11-15—NACE Annual Conference, Kiel Auditorium, St. Louis, Missouri.

May 20-22—Northeast Region Corrosion Control Conference, Syracuse University, Syracuse, N. Y.

1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

SHORT COURSES

1956

Sept. 10-14—Corrosion Short Course, Ohio State University, Columbus.

Sept. 20-21—Sixth Annual Corrosion Control Short Course, Shreveport Section, Centenary College, Shreveport, La.

L. D. COOK

L. D. Cook, sales engineer for Bart Manufacturing Corp., Detroit and recently elected secretary-treasurer of North Central Region NACE was killed in an aircraft accident June 30. He was among the 128 persons killed in the collision of Trans-World Airlines and United Air Lines planes over the Grand Canyon.

Mr. Cook, formerly head materials engineer with Wyandotte Chemicals Corp. and a consultant on application of materials for use in production processes, was one of the organizers and founders of Detroit Section NACE. He also was a member of ACS, ASM and ASTM.

His survivors include his widow and three children.

Permian Basin Section

The June 11 meeting of Permian Basin Section held in the Lincoln Hotel in Odessa was attended by approximately 75 members and guests.

Willard R. Scott, Director of Research for Crest Research Laboratories, Inc., Seattle, Washington, spoke on Laboratory Tests and Data Relevant to Field Application of Corrosion Inhibitors.

Next meeting of the section will be in the Midland Club, Midland, Texas.

Alphabetical author indices in the December issue of Corrosion include titles of papers written by or discussed by persons listed.

REGIONAL S and COURSES

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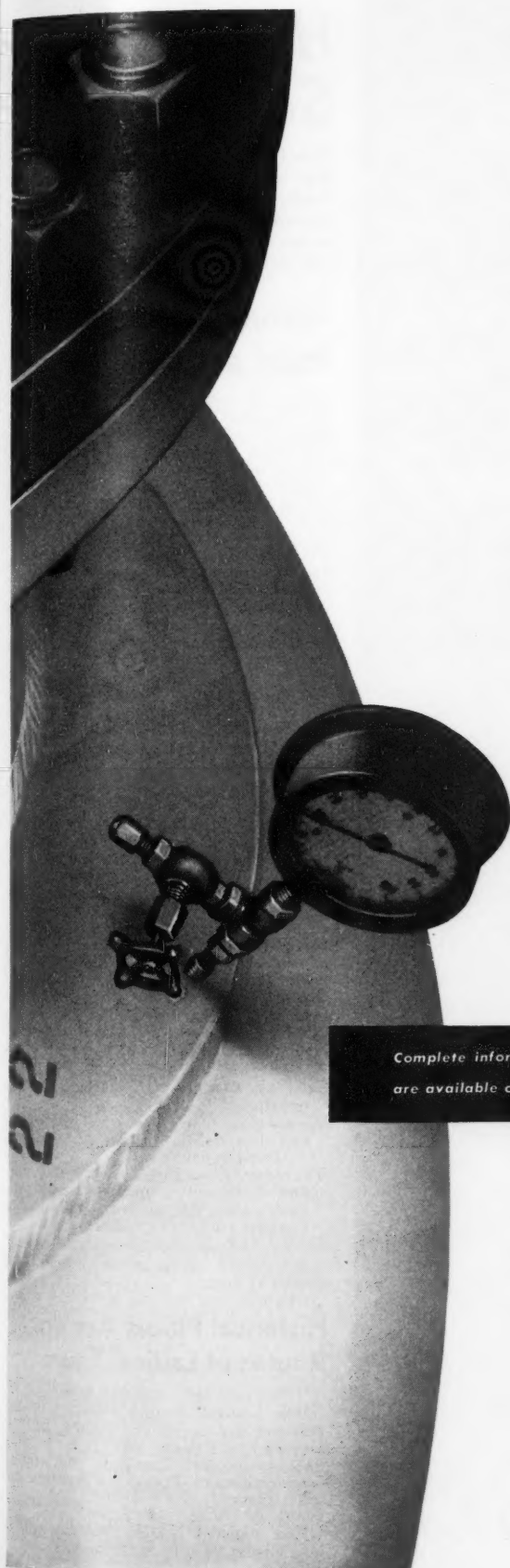
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AKR 56-H



History and San Antonio

Top and middle photographs at left are scenes along the San Antonio River, which runs through San Antonio's business district. Lower scene is at La Villita, reconstructed Mexican village.

Annual Banquet to Be Held at La Villita

The distinctive atmosphere of Old San Antonio will prelude the South Central Region's annual banquet party at La Villita on the night of October 25. La Villita is a restoration of the original settlement on the San Antonio River which preserves the authentic air of the first Spanish settlement.

Dinner will begin at 7 pm in Hidalgo Plaza after which a one-hour "International Revue" will be presented in the Arneson Theater on the banks of the San Antonio river. Spectators are seated in an open-air amphitheater on one side of the stream and the stage is located on the other.

An orchestra will play for listening and dancing in Juarez Plaza following the revue.

Tours, Banquet Are Among Ladies' Program Events

Several entertainment features and an especially interesting program for ladies have been arranged for the South Central Region's October 23-26 meeting at San Antonio. Highlight of the meeting, insofar as entertainment is concerned, will be the annual banquet party at La Villita, a Mexican village reconstructed as it was on the banks of the San Antonio river when Texas was first settled by the Spanish.

Everyone registered also will be invited to attend the Fellowship Hour.

The ladies program has been arranged as follows:

Tuesday, Oct. 23—Ladies hospitality program.

Wednesday, Oct. 24—Ladies coffee hour and hospitality, sight-seeing tour, Fellowship Hour.

Thursday, Oct. 25—Ladies coffee hour and hospitality, luncheon and style show (St. Anthony Hotel), annual banquet party. (La Villita).

Friday, Oct. 26—Ladies hospitality hour.

All events will be at the Gunter Hotel except as noted.

Historical Places Are on Routes of Ladies' Tours

Tours planned for ladies attending the South Central Region meeting in San Antonio will cover The Alamo, Spanish Governor's Palace, San Jose Mission, Chinese Sunken Gardens, the original fortifications of Fort Sam Houston and other places.

Five regional NACE meetings will be held during the fall of 1956.

and Beauty Are Attractions

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Top right is the world famous Alamo, "Shrine of Texas liberty." Center view is of the Sunken Gardens in Brackenridge Park while bottom view is another scene from La Villita, where annual banquet will be held.

Varied Subject Matter In Technical Program

Six symposia and numerous meetings of technical committees will be held during the South Central Region's Meeting October 23-26 at San Antonio. For the first time at a regional meeting, an exhibition of corrosion control materials and processes will be held concurrently with the meeting.

Events outlined for the technical program are:

Tuesday, October 23

Technical committee meetings (See schedule in Technical Committee Activities Section).

Wednesday, October 24

Technical committee meetings.
Exhibition opens.

Thursday, October 25

Symposia: Corrosion in Pipe Line Industry, Elevated and High Temperature Corrosion, Corrosion in Oil and Gas Well Equipment, Corrosion in the Utilities Industry.
Technical Committee meetings.
Exhibition

Friday, October 26

Symposia: Cathodic Protection, Corrosion in Transportation Industry.
Technical committee meetings.
Exhibition.

Full Schedule of Business And Social Events Arranged

A schedule of business and social events has been arranged as follows for the South Central Region's October meeting in San Antonio:

Tuesday, October 23

Registration.
Ladies' hospitality program.

Wednesday, October 24

Registration.
Ladies coffee hour.
Regional officers' and trustees' luncheon.
Ladies' sight-seeing tour.
Fellowship Hour.

Thursday, October 26

Registration.
Authors' breakfast.
Ladies' hospitality hour.
Ladies' luncheon and style show.
Annual banquet and party.

Friday, October 25

Registration.
Authors' breakfast.
Ladies' hospitality hour.
Annual business luncheon.



Southwest Institute Tour

A tour of Southwest Research Institute will be available for persons attending the South Central Region meeting in San Antonio if there is sufficient interest.

Judson S. Swearingen, director of the institute's petroleum division will speak at the annual business luncheon October 26.

Mexican Air Tour Offered

For those who may be interested, plans have been made for a week-end tour by air of Mexico after the San Antonio meeting has ended.

Subscribers to NACE's Abstract Card Service receive cross-indexed abstracts of most of the available literature on corrosion.

Southeast Region Meeting

The fall 1956 meeting of Southeast Region will be held November 8-9 at Charlotte, N. C.

East Texas Section

Charter of the East Texas Section has been approved by South Central Region.

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GENERAL NEWS

Sea Horse Institute Has Eight Technical Sessions

The June 4-8 Annual Sea Horse Institute held at Wrightsville Beach, N. C. was attended by 266. Eight sessions were devoted to metals, cathodic protection, coatings and miscellaneous topics and three to marine borers.

Guided tours were made to atmospheric test lots at Kure Beach where some 30,000 specimens are exposed and to Harbor Island Test Station where numerous sea water immersion, full scale sea water evaporators and laboratory tests are in operation.

Two technical committees of the National Association of Corrosion Engineers met during the week. At the T-3G-1 meeting on Cathodic Protection of Ship Hulls 31 were present while 25 attended the session of T-3G-2 on Cathodic Protection of Heat Exchangers.

Registration Limited at Ohio State Short Course

The September 10-14 Short Course in Corrosion to be held at Ohio State University is limited to 150 registrants. Certificates will be presented to those who attend the entire series of lectures.

Registration fee of \$35, which includes price of a luncheon, must be paid in full before August 27 to: Ohio State University, Department of Metallurgical Engineering, 114 Lord Hall, Columbus 10, Ohio.

Housing in men's dormitories is available at \$3 per night.

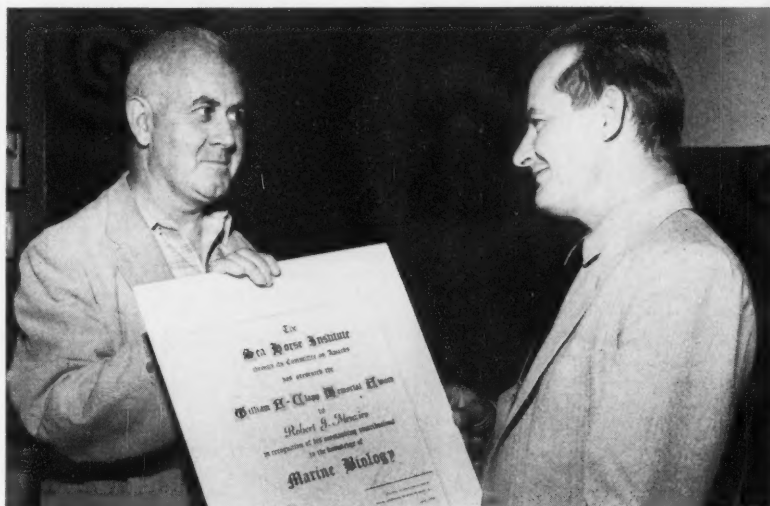
Lectures are designed to give a comprehensive outline of fundamentals of corrosion as well as consideration to practical problems. A complete program was published in CORROSION, July, Page 92. One addition has been made as follows: Friday, Sept. 14, Theories on Passivity of Metals, R. Speiser, Ohio State University.

The course, being given with cooperation of NACE, will have five past presidents of the National Association of Corrosion Engineers as participants. Most of the other lecturers are NACE members also.

Abstracting Offered on Quality Control, Statistics

Quality Control and applied statistics abstracts will be the title of a loose-leaf abstract service to be operated by Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y. More than 400 journals will be scanned for articles on quality control, operations research and industrial application of statistical methods. One volume of about 1000 pages yearly divided among 12 issues beginning in June 1956 is contemplated.

Corrosion selects information on corrosion work by organizations other than NACE and publishes it monthly.



THE 1956 CLAPP AWARD for achievements in marine biology is shown being given here by F. L. LaQue, The International Nickel Co., Inc. to Robert J. Menzies, Lamont Observatory, Columbia University. Dr. Menzies began his work in marine biology before graduation from high school. He was organizer of the Southern California Marine Borer Council and has published numerous technical articles on his specialty.

Book Reviews

Proceedings, Vol. 55, 1955. 1250 pages, 6 x 9 inches, cloth, May, 1956. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Availability not indicated.

Committee reports and technical papers offered to ASTM during 1955 and accepted. A list of special technical publications issued by the society in 1955 is included.

Index to the 19th Semiannual Report to Congress, U. S. Atomic Energy Commission. 34 pages, 6 x 9, paper, July, 1955-December, 1955. Superintendent of Documents, U. S. Govt. Printing Office, Washington 25, D. C. Per Copy, 15 cents.

An alphabetical author and subject index of the subject report.

ASTM Standards on Light Metals and Alloys. 276 pages, 6 x 9 inches, paper, December, 1955. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy \$3.50.

Numerous specifications are given on aluminum and aluminum-base alloys, including ingots, castings, bars, rods, wire and shapes; forgings, pipe and tubes, sheet and plate, wrought products for electrical purposes, filler metal, electroplating; magnesium and magnesium-base alloys, including ingots, castings, bars, rods and shapes; forgings, sheet, tubes.

Tentative Methods of Tension Testing of Metallic Materials and Standard Methods of Sampling Wrought Non-Ferrous Metals and Alloys for Determination of Chemical Composition are included.

Basic Effects of Environment on the Strength, Scaling and Embrittlement of Metals at High Temperatures. 120 pages, 6 x 9 inches, paper, Sept. 1955. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, \$2.75.

Papers presented February 2, 1955 at a symposium of the same title as the book are published. Included are: The Role of Thin Surface Films in the Deformation of Metal Monocrystals, John J. Gilman; Structure of Oxides Formed on High-Temperature Alloys at 1500 F, John F. Radavich; Effect of Strain on the Oxidation of Nickel-Chromium Heater Alloys, Earl A. Gulbransen and Kenneth F. Andrew;

An Investigation of Intergranular Oxidation in Type 310 Stainless Steel, R. E. Keith, C. A. Siebert and M. J. Sinnott; The Properties of Oxidation-Resistant Scales Formed on Molybdenum-Base Alloys at Elevated Temperatures, M. Gleiser, W. L. Larsen, R. Speiser and J. W. Spretnak; Oxidation at Elevated Temperatures, John F. Radavich.

Discussions to the papers are included.

Symposium on Atmospheric Corrosion of Non-Ferrous Metals. 158 pages, 6 x 9 inches, Paper, May, 1956. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, \$2.75.

Consists of papers presented at the ASTM meeting, Atlantic City, N. J., June 29, 1955. Results are given of 20-year exposure tests on non-ferrous metal

(Continued on Page 86)

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BOOK REVIEWS

(Continued from Page 85)

samples at seven sites. Papers are included on parallel tests on similar materials by others as well as galvanic couple tests.

Most of the samples discussed were exposed for periods of about 20 years. Materials include aluminum-base alloys, copper alloys, galvanic corrosion of magnesium coupled to other metals, atmospheric corrosion of rolled zinc, use of tin and lead outdoors and atmospheric corrosion behavior of some nickel alloys.

Corrosion Resistance of Non-Metallic Materials. (In German) 232 pages, 6½ x 9½ inches, cloth, 1956. By Franz Ritter. Springer-Verlag, Vienna, Austria. Per copy, \$8.35.

Resistance of numerous synthetic and natural non-metallic materials are tabulated under an alphabetical listing of corrosives. Temperature limits are indicated.

Rust Damage and Protection Against Rust. (In German) 247 pages, 5¼ x 8 inches, cloth, 18 Jun 1956. By Bruno Waeser. Wilhelm Pansegrau Verlag, Uhlandstrasse 102, Berlin-Wilmersdorf, Germany. Per copy, DM 28.80. Theoretical and practical considerations involved in the protection of iron against rust are discussed. Sections cover theory, German patent literature, protection by organic and inorganic coatings, cathodic protection, characteristics of different kinds of iron alloys and testing methods. There are extensive references after each section and alphabetical subject and author indexes.

CERTIFICATES of MEMBERSHIP in NACE

Certificates of membership in the National Association of Corrosion Engineers will be issued on request at \$2 each, remittance in advance. The certificates, which measure 5½ x 8½ inches, are signed by the president and executive secretary of the association.

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Certificates measuring 9 x 12 inches in size, prepared from an engraved plate, are available for issuance to regional and sectional chairmen. They will be supplied on request of the region or section at \$7.50 each to be paid by the region or section, the cost to be classified as a non-reimbursable expenditure.

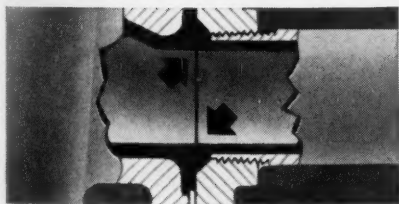
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valves form snug, tight-fitting, leak-proof joints ... is available for working pressures up to 150 psi. Valves and fittings are also available in steel for working pressures to 300 psi. This modern piping is easily installed, too. It can be cut and threaded in the field with available pipe fitters' tools. Its rigidity means few supporting structures are needed. For further information on saran lined pipe, fittings and valves, send in the coupon on the left. THE DOW CHEMICAL COMPANY, Midland, Michigan.

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is customarily supplied in the 8-10 mil range; however, it can be plated up to 15-20 mils, if specified.

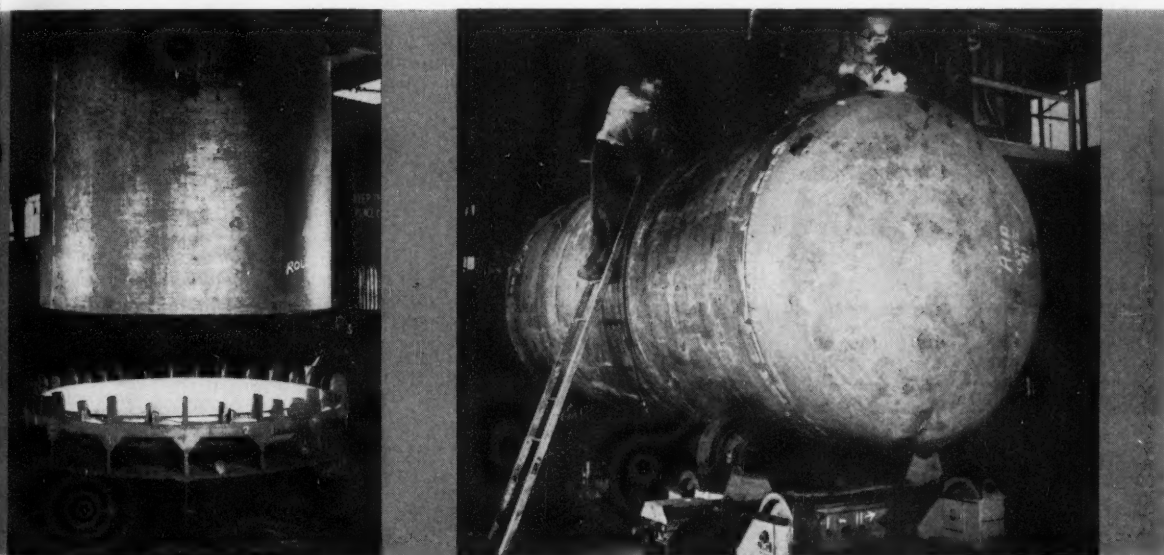
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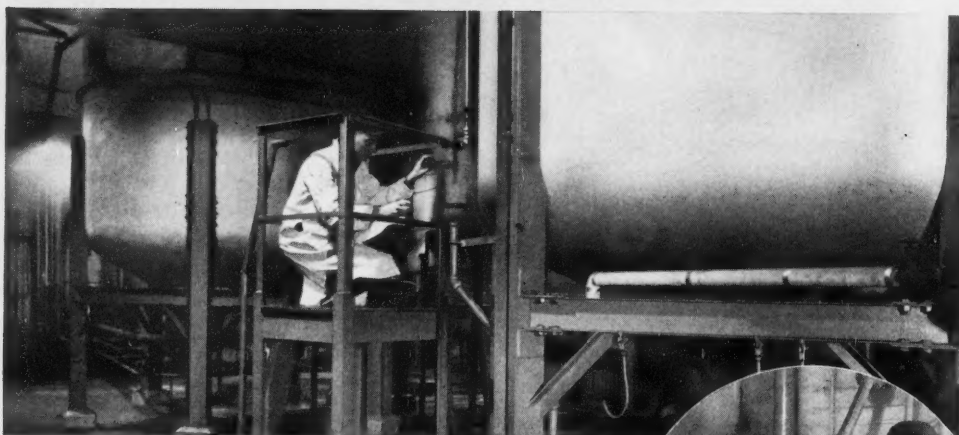


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PAINT LEADS A HARD LIFE in the steamy antibiotics plant of the New York Quinine and Chemical Works. Day in and day out, paint endures live steam and high temperatures. The coating on the processing equipment is exposed to hydrochloric acid and caustic soda. All surfaces take frequent hosing and scrubbing.

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rosion by chemicals and moisture, excellent adhesion to metals, plaster and concrete, and because of its glossy finish has reduced dust settling.

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If you have a paint maintenance problem ... where ordinary paints just can't take it—ask your paint supplier for Epon resin-based paint. You'll find that it is unsurpassed as an all-purpose industrial coating! Call on Shell Chemical sales offices for names of suppliers. Write for the full Epon resin coatings story, "Planning to Paint a Pyramid?"

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NEW PRODUCTS

Materials
Literature

Nicolet Industries pipe line felt reinforced with glass strand is covered in a brochure available from Middle West Coating and Supply, 409 Daniel Bldg., Tulsa, Okla. Samples of the reflective felt are included.

Petroleum Sulfonates added to the series produced by Pennsylvania Refining Co., Butler, Pa. include a calcium sulfonate, a barium sulfonate and two sodium sulfonates. These materials are recommended as emulsifiers, solubilizers, dispersers and rust preventives. Alkosul 645, a sodium sulfonate made from a synthetic alkylate feedstock may be used as a rust preventive.

Arsonosiloxanes, compounds developed by Central Research Laboratories of American Smelting and Refining Co. and E. F. Houghton & Co. have water repellent qualities of conventional silicones and fungicidal and pesticidal properties of the arsenicals.

Southern California Edison Company expects to pass the billion dollar mark in plant investment this year.

National Carbon Company, a Division of Union Carbide and Carbon Corp. will open a new basic research laboratory September 18 in Parma, Ohio, a suburb of Cleveland. Chemical and solid

state physics will be studied. About 350 persons will be employed, including 150 scientific and technical personnel.

Carboline Products will be distributed in Alabama and Mississippi by Specialty Supply Co., Mobile, Ala.

M-252, a comparatively new vacuum melted nickel-base alloy is proving suitable for extended operation under load at temperatures up to 1240 F. General Electric's Gas Turbine Department, Schenectady says the alloy is being used in forged buckets in the first stage of heavy-duty gas turbines.

DeVilbiss Company's fall spray finishing school sessions will be held for one week each beginning on August 13, September 10, October 8, November 5 and December 10. All users of DeVilbiss equipment are invited to send trainees. No tuition is charged. Application blanks are available from the company at 300 Phillips Ave., Toledo 1, Ohio.

Engineering Properties of Ductile Ni-Resist Austenitic Irons, a 20-page and cover bulletin available from Reader Service Dept., The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y. describes the properties of this material. Corrosion resistance is given in a table showing ipy values for several corrosives. The bulletin is amply

illustrated and has copious tabulated information.

Corban liquid and stick formulations are described in a series of bulletins incorporated in a letter-size file available from Dowell, Incorporated, P. O. Box 536, Tulsa 1, Okla. General recommendations respecting use of the materials in treating sour crude wells and other corrosive wells is included.

Acco Aluminized Wires are described and illustrated in Bulletin DH-537 available on request from Page Steel and Wire Rope Div., American Chain and Cable Co., Inc., Monessen, Pa. The 12-page illustrated folder gives principal uses for and description of the properties of the material.

Non-Destructive Testing of engineering materials is available from Houston Gamma Ray Co., 5412 Schuler St., Houston. The firm uses Magnaflux, Magnaglo and Zygo as well as radiographic methods.

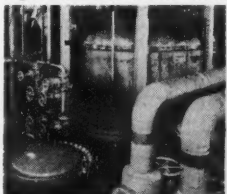
Fans constructed of polyvinyl chloride and epoxy resins reinforced with fiberglass are offered in sizes from 6 to 24-inch inlets. The fans are described in a bulletin available from duVerre, Inc., 374 Delaware Ave., Buffalo 2, N. Y.

(Continued on Page 92)

The DEL coating used in the centrifuge area withstands one hosing down every shift.



DEL Protective Coating is used on processing vessels and piping not made of stainless steel.



Despite constant exposure to live steam, this tank shows no wear. It is protected with DEL.



All-purpose

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protective coatings

resist heat, humidity, chemicals and frequent scrubblings

minimize maintenance painting at New York Quinine & Chemical Co., Newark, N.J.

Few conditions are as hard on a paint as those found in an antibiotics plant.

At New York Quinine & Chemical Company, Newark, N. J., geysers of live steam from pilot vents constantly keep plant temperatures high, humidity close to 100%! Installations are unavoidably exposed to hydrochloric acid, caustic soda and other processing chemicals' fumes. In addition, the need for absolute cleanliness demands that floors and process vessels be hosed down regularly to prevent bacterial growth.

To meet these trying conditions, DEL Protective Coatings are used. Today, after 4 years' exposure to heat, humidity, chemicals and daily scrubblings, DEL Protective Coatings have helped keep New York Quinine's plant in excellent shape; very little maintenance painting is needed.

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DEL Protective Coatings are ideal where exceptional chemical resistance is a *must*! You'll find a DEL coating especially designed for protecting metal, masonry or wood against acids, alkalis, alcohol, oil, gasoline, solvents, salts or water. DEL Protective Coatings are formulated for use on new construction as well as plant maintenance, processing equipment and products finishing. There are DEL coatings for interior and exterior uses; many come in a variety of pastel colors.

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NEW PRODUCTS

(Continued from Page 91)

Liquid Neoprene available from Wilbur & Williams Co., 130 Lincoln St., Boston 35, Mass. is available in black, red, light gray and aluminum. A 4-page folder describing the formulation is available on request.

An Engineering center will be constructed adjacent to the Garland, Texas plant of Temco Aircraft Corp., Dallas.

Koppers Company has purchased a 176-acre tract near Monroeville, Pa. as site of a new research center. Scope of Koppers' research program is expected to be tripled in the next 10 years, according to Paul W. Bachman, vice-president and director of research.

Teflon rod in diameters from 0.125-inch to one inch are offered in increments as low as 1-32 inch in popular diameters by Tri-Point Manufacturing, Inc., 401 Grand St., Brooklyn 11, N. Y.

Stewart Dual Electrolysis Voltmeter, with a range from 2.5 millivolts to 300 volts is available from Stewart Brothers, Division of Instrument Laboratories, 315 W. Walton Pl., Chicago 10, Ill. Both meters on the two-meter device are accurate to 1 percent of full scale. Zero center type meters prevent confusion about polarity.

Reynolds Aluminum Digest, a monthly periodical available free of cost from Desk ES, Reynolds Metals Co., 2500 South Third St., Louisville 1, Ky. carries condensations of articles published in the technical press. The publication is 32 pages and cover, 8½ x 11 inches and illustrated. Patents also are listed.

I & E, Diesel driven, air cooled portable air compressors made in West Germany and imported for sale in the United States by Air Compressors Inc., 2339

West Beaver St., Jacksonville, Fla. are made in three sizes. All machines from 55 cfm to 320 cfm capacity are said by manufacturers to be lighter than comparable liquid cooled compressors.

Gencote 108, a Teflon-based coating, has an electrical resistance across 4 mils of about one ohm. The electrically conductive material can be applied over insulating bases such as glass, ceramics and porcelain. Reduced friction and static sparking are among the advantages gained through its use. General Plastics Corp., Paterson, N. J. is manufacturer.

Superior Tube Company, Norristown, Pa. has published Data Memorandum No. 4 describing its tubing with outer diameters from 5.8 to 2½ inches with wall thicknesses of 0.035-inch or less. Tubing is produced in more than 20 analyses of stainless, nickel and nickel alloy, carbon and alloy, beryllium copper and titanium.

Durco Corrosion Resisting materials may be selected by use of Bulletin A/5 available from The Duriron Co., Inc., Dayton 1, Ohio. Resistance of the principal Durco materials to a long list of corrosives is tabulated.

MEN in the NEWS

Harvey Fansher is Midwest representative of Corrosion Rectifying Co., Houston, with offices at Great Bend, Kans. He is a graduate of Kansas State College, Manhattan, Kans. and was a consulting engineer before taking his new post.

Frank R. Caldwell, an experimental physicist has been named head of the Combustion Controls Section of the Mechanics Div., National Bureau of Standards.

John G. Seiler has been elected president of Tube Turns, Louisville, Ky.

James T. MacKenzie, retired technical director of American Cast Iron Pipe Co., Birmingham, Ala. and now with Southern Research Institute has been given a certificate of honorary membership in the American Society for Testing Materials.

William F. Burchfield has been appointed supervisor and **Kenneth M. Spicer**, assistant supervisor of Technical Service in the International Nickel Company's Development and Research Division. Mr. Burchfield has been with Inco since 1929 and Mr. Spicer since 1928.

W. A. Wood, Products Research Service, Inc., **Joe Rench**, Napko Paint Co., **F. A. MacDougall**, Shell Oil Co., **Fred Gartner, Jr.**, F. W. Gartner Co. and **R. W. Fogal** of Levinson Shipyard were members of a panel discussing coatings at a June 12 session at Harvey, La. Continental, Shell and the California Company sponsored afternoon and evening sessions attended by shipyard personnel, applicators and engineering personnel from the companies. Application of modern plastic coatings was the principal topic.

Ed Smart has been named sales engineer for Corrosion Resistant Products, Inc., a division of Loven Chemical of California. The company operates in eleven Western states.

Lawrence N. Canjar, associate professor of chemical engineering at Carnegie Institute of Technology has been awarded a \$6000 research grant by National Science Foundation for research in phase equilibria and thermodynamic data of mixtures.

George Orr has been named Southeastern District salesmanager for Hill, Hubbell & Co., Division of General Paint Corp. Mr. Orr has had years of experience with Columbia Gas System and United Fuel Gas Co. His headquarters will be Charleston, W. Va.

William R. Curley has been named sales engineer by Royston Laboratories in the states of Louisiana, Arkansas, Mississippi, Missouri and Western Tennessee. Formerly with Interstate Natural Gas Co., Monroe, La. his headquarters will be at Monroe.

Marion Y. Hibler, formerly with Southern Union Gas Co. at Austin has been named superintendent of the company's Galveston, Texas system.

John G. Fox has been named head of the Department of Physics and **Roger B. Sutton** director of the Nuclear Research Center at Saxonburg of Carnegie Institute of Technology, Pittsburgh. Both are natives of Canada.

W. A. Mudge has been appointed special representative on educational programs of The International Nickel Company of Canada, Ltd.

Charles D. Branson is now assistant director of research of Robertshaw-Fulton Controls Company. He will be at the company's research center at Irwin, Pa.

Charles C. Bonin has been named engineering manager, **H. K. Fairbanks**, chief concrete-hydraulic engineer and **G. F. Latham**, chief architectural-structural engineer of Ebasco Services, Inc.

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CORROSION ABSTRACTS

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Vol. 12 August, 1956 No. 8

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2. TESTING

2.3 Laboratory Methods and Tests

2.3.7
Tolansky Gauge for Rapid Measurement of Film Thickness. T. M. GREEN AND L. N. HADLEY. *J. Opt. Soc. Amer.*, 45, 228-229 (1955) March.
The thickness of a thin film can be determined rapidly with an accuracy of 50 Angstrom units by a device utilizing the Tolansky interference method. Based on the displacement obtained when light passes through a plane sheet of glass at oblique incidence, the instrument enables fringe shift and spacing to be determined at a single observation. The film thickness can then be readily calculated.—NSA. 10552

2.3.7, 5.9.4
Thickness and Breakdown Voltage of an Anodic Oxide Layer. (In Italian). A. PRATI. *Alluminio*, 24, No. 2, 111-119 (1955) March.
The breakdown voltages of Aluminite coatings on 99.5 percent aluminum, aluminum-3.5 percent magnesium and aluminum-1 percent silicon-magnesium de-

termined using the ISML Resistometer. Results are analyzed statistically to evaluate the suitability of the test as a method for determining thickness.—BNF. 10620

2.3.7, 7.3

Laboratory Installation for the Service Testing of Pump Piston Rods for Corrosion Fatigue. (In Russian.) R. A. BAGRAMOV. *Zavodskaya Laboratoriya* (Factory Laboratory), 21, No. 7, 864-866 (1955) July.

Testing simulates actual oil-well pumping conditions, including variable asymmetric loads. Diagrams, graphs.—BTR. 10476

2.3.8

Equipment for Oil and Petrochemical Process Development. H. HOOG, J. J. LEENDERTSE AND H. REITSMA. *Ind. & Eng. Chem.*, 47, No. 6, 1104-1116 (1955) June.

Process development and pilot plant activities, with particular emphasis on equipment, of Amsterdam laboratories of the Royal Dutch-Shell Group. To aid in selection of proper construction materials for commercial plant, corrosion test plates in standardized holders are placed in pilot plant. Cutaway view of corrosion test assembly is shown. Detailed information on equipment for pilot plants for continuous sulfonation of hydrocarbon fractions, for high-pressure catalytic pilot plant, for deasphalting unit, batch distilling units and for general purpose autoclaves and auxiliaries lists AISI 321, Croloy 7, cast iron and Hastelloy B among materials. Tables, photographs.—INCO. 10375

2.3.8, 2.4.2

Corrosion Monitoring for Chemical

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AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.
BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.
BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.
BNF—Bulletin; British Non-Ferrous Metals Research Association, 81-91 Euston St., London NW 1, England.
CBE—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 rue des Drapeaux, Brussels, Belgium.
CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
EL—Electroplating, 83/85 Udney Park Road, Teddington, Middlesex, England.
EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.
IIM—Transactions, The Indian Institute of Metals, 23-B, Notoji Subhas Road, P. O. Box 737, Calcutta, India.
INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.
IP—Institute of Petroleum, 26 Portland Place, London Wc2, England.
JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguroku, Tokyo, Japan.
MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.
MI—Metallurgia Italiana, Associazione Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.
MR—Metals Review, American Society of Metals, 7301 Euclid Ave., Cleveland 3, Ohio.
NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.
NBS—National Bureau of Standards, Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.
NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.
PDA—Prevention Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.
RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.
RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.
SE—Stahl und Eisen, Verlag Stahlisen, M. B. H., Dusseldorf, August-Thyssen Str. 1. Postcheck Koln 4110, (22a) Dusseldorf, Germany.
TIME—Transactions of Institute of Marine Engineers, 85 The Minories, London EC 3, England.
UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.
ZDA—Zinc Development Association, 34 Berkeley Square, London W.1.

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NACE will NOT accept orders for photoprint or microfilm copies of material not published by the association.

Plant, C. EDELEANU. *Corrosion Technology*, 2, No. 7, 204-208 (1955) July.

Experiments described indicate that the potential measurement corrosion monitoring system available on present small scale pilot plant allows its exposure to very corrosive solutions without causing undue damage. Equipment necessary for monitoring need not be more complicated than instruments used for recording pH or those used in monitoring cathodic protection. Data are presented for corrosion of various stainless steels (18-8, 18-8 titanium, 18-8 molybdenum, 18-8 molybdenum-copper) in sulfuric acid. Time potential curve is plotted for 12-12 chromium-nickel steel corroding in 2.5 percent sulfuric acid at room temperature.—INCO. 10523

2.4.3, 2.3.7

Use of Radioactive Isotopes to Control the Homogeneity of Solid Bodies

and Determine Linear Dimensions. (In Russian.) M. B. NEIMAN. *Stanki i Instrument*, 26, No. 4, 1-5 (1955) April.

Application of xeroradiography; determination of corrosion, wall and coating thicknesses. Diagrams, graphs, 21 references.—MR. 10592

2.4 Instrumentation

2.4.3, 3.7.3, 1.2.5

Gamma-Radiography in Oil Storage Installations. Part IV. C. C. BATES. *Atomics* (British), 6, 144-147, 150 (1955) May.

Health and safety precautions applicable in this type of work. New method of nondestructive testing enables very high standard of weld inspection to be achieved. Photographs.—MR. 10484

2.4.3, 6.4.2

Superposition Interference in X-ray

Testing of Large Parts. (In German.) F. EBERT AND H. G. DIERCKS. *Aluminium*, 31, No. 7/8, 3-35-337 (1955) July-August.

Sometimes reflections are obtained in the radiographs of light alloy castings not arising from defects but due to non-random scattering of the primary radiation: occurs if grain is macroscopic, texture uniform. Interference spots may be differentiated from flaws as they change to different positions when object is moved slightly.—BNF. 10754

2.6 Preparation and Cleaning of Specimens

2.6, 6.4.2

A Method for the Isolation of Surface Films from Aluminum Alloys and the Mechanism of the Reactions Involved. M. J. PRYOR AND D. S. KEIR. *J. Electrochem. Soc.*, 102, No. 7, 370-381 (1955) July.

Warm solutions of iodine in methanol were found satisfactory for isolating surface films from aluminum alloys not containing copper. Addition of sulfosalicylic acid to these solutions renders them satisfactory for isolation of films from aluminum-copper alloys. Attack is not selective at the film-metal interface, so all aluminum must be dissolved before uncontaminated films can be obtained. Hydrogen evolved during dissolution of the aluminum is believed due to the formation of aluminum methoxide. Iodide ions are also formed in these solutions. Aluminum methoxide is insoluble in dehydrated solutions but is decomposed by traces of water to soluble reaction products. A mechanism for the dissolution of aluminum in iodide-methanol solutions is suggested.—ALL. 10615

3. CHARACTERISTIC CORROSION PHENOMENA

3.1 General

3.1, 1.3, 5.11

Corrosion: How It Affects Materials Selection and Design. Materials & Methods Manual No. 121. R. W. HENKE. *Materials & Methods*, 42, No. 5, 119-134 (1955) November.

Comprehensive review of types and mechanisms of corrosion and how corrosion can be reduced by proper design. A layman's definition of corrosion is given and methods of expressing rate of corrosion are considered. Galvanic corrosion, crevice corrosion, chemical attack dezincification, graphitization, caustic embrittlement, hydrogen embrittlement, intergranular corrosion, stress corrosion cracking, corrosion fatigue, impingement corrosion, erosion, fretting and cavitation corrosion are discussed and appropriate diagrams given. An accompanying chart rates corrosion resistance to corrosive chemicals and foodstuffs of various materials including nickel silver, Monel, Hastelloy D, copper-nickel (Waukesha 20) and stainless steels.—INCO. 10783

3.2 Forms

3.2.2, 3.5.6

Hydrogen Occlusion and Equilibrium Hydrogen Pressure in Steel During Electrolytic Charging. (In English.) F.

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DE KAZINCZY. *Jernkontorets Ann.*, 139, No. 7, 466-480 (1955).

Investigation of hydrogen diffusion through steel membranes; its relation to current density; no relation was found between hydrogen flow and overvoltage; equilibrium hydrogen pressure and the formation of blisters.—BNF.

10744

3.2.2, 3.6.2

Filiform Corrosion, A New Type of Corrosion (In German.) A. BUKOWIECKI *Schweiz. Archiv angew. Wiss. u. Tech.*, 21, No. 5, 164-168 (1955) May.

A study of filiform corrosion is presented. Results of experiments and tests conducted by various research workers are reviewed and it is concluded that 1) aluminum and magnesium are subject to filiform corrosion 2) there is no correlation between the structure of the metal and the pattern of the corrosion lines 3) filiform corrosion was observed under layers of various transparent and pigmented paints. The ordinary corrosion protective coatings with the exception of phosphate layers, did not prevent the formation of filiform corrosion. 4) microorganisms have no contribution to filiform corrosion 5) there is a definite correlation between relative humidity of the air and the formation of filiform corrosion instead of other types of corrosion. In addition to these empirical facts the remarkable observation was made that the lines never cross and seldom fork. The mechanism of filiform corrosion is analyzed, its speed of propagation and its occurrence on highly polished and unprotected metal surfaces is discussed.—ALL.

10493

3.2.2, 6.2.5, 3.7.1

An Investigation of Intergranular Oxidation in Type 310 Stainless Steel. R. E. KEITH, C. A. SIEBERT AND M. J. SINNOTT. Paper before Am. Soc. Testing Materials Symp. on Basic Effects of Environment on the Strength, Scaling, and Embrittlement of Metals at High Temperatures, Cincinnati, February 2, 1955. ASTM Special Technical Pubn. No. 171, 1955, 49-60; disc., 60-64.

Investigation was undertaken to establish effects of time and temperature on intergranular oxide penetration and to determine whether appreciable differences in composition exist between the intergranular oxides and external scales. To ascertain the effects of minor alloy compositional variations on the severity of intergranular attack, specimens from a number of different heats were studied. Depths of intergranular oxide penetration was not affected appreciably by minor variations in alloy composition. Depth increased with time and temperature of oxidation. A mechanism of intergranular oxidation was proposed in which the movement of oxygen is conventional intergranular diffusion. The formation of the intergranular oxide is not grain boundary diffusion-controlled and probably depends on the presence of suitable metal ions and nucleation sites, as well as on the oxygen itself. 19 references.—INCO.

10809

3.2.2, 6.3.6

Dezincification of Brasses in Marine Environments. L. KENWORTHY AND W. G. O'DRISCOLL. *Corrosion Technology*, 2, No. 8, 247-249 (1955) August.

Mechanism of the process and factors influencing dezincification are discussed, including structure and composition of the alloy and effect of environment. 25 references.—INCO.

10434

3.2.3

Staining of Engineering Components.

R. GRAHAM. *Corrosion Technology*, 2, No. 9, 275-277 (1955) September.

Considers the stain stage of rusting as period at which it is possible to obtain maximum amount of information on the rusting process. Possible compounds involved, their properties and factors influential in determining a particular type of and product (oxygen concentration, pH value, humidity, and effect of surface finish) are discussed. Mechanism of change of ferrous hydroxide to either hydrated ferric hydroxide or hydrated ferrosulfate is investigated, and α , β and ν modifications of ferric hydroxide are reviewed. Staining on track of taper roller bearing serves as illustration. Preventive measures dis-

cussed include grease, oils and vapor phase inhibitors.—INCO.

10583

3.3 Biological Effects

3.3.4, 1.6

A Study of Galvanic Corrosion in Marine Pseudo-Sediments. WILLIAM G. BRADLEY. Texas Agricultural and Mechanical College, Dept. of Oceanography, Tech. Rept., A & M Project 24-A, Reference 54-52T, September, 1954, 73 pp.

To study the mechanism of anaerobic corrosion of iron by sulfate-reducing marine bacteria, monometallic couples of SAE 1020 steel and 61S-T6 aluminum alloy were exposed as concentration cells in pseudomarine environments. These

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cells simulate a natural system in which a single piece of metal is exposed through the interface between marine sediments and the overlying sea water. In such cells, the effects of marine sulfate-reducing bacteria are superimposed over the physico-chemical redox system.

That sulfate-reducing bacteria are apparently capable of depolarizing a steel cathode was the most important single finding of these studies. Electrode potential data showed that the strain of sulfate reducers (*Desulfovibrio desulfuricans*) used in these experiments causes a change in the cathode compartments of cells containing mild-steel electrodes in nutrient medium. This can result in as much as a 200-fold increase in galvanic current. Similar cathodic areas may exist in oxygen-free marine environments.—PDA. 10659

3.5 Physical and Mechanical Effects

3.5.7, 3.8.4, 3.2.3

High Pressure Oxidation of Metals: Oxidation of Metals Under Conditions of a Linear Temperature Increase. JOHN P. BAUR, DONALD W. BRIDGES AND W. MARTIN FASSELL, JR. *J. Electrochem. Soc.*, 102, 490-496 (1955) August.

Studies on tantalum, niobium, molybdenum, copper, zirconium, magnesium, titanium and tungsten to develop a method whereby oxidation can be surveyed quickly and the pressure sensitive region found. Graphs, tables, 23 references.—BTR. 10520

3.5.8

Fretting and Fretting Corrosion. *Lubrication*, 41, 85-96 (1955) August.

Scope; detection; mechanism. Effects of lubrication and other factors which influence fretting. Photographs, diagram, tables, 26 references.—BTR. 10454

3.5.8

Metal Transfer and the Wear Process. M. KERRIDGE, *Proc. Phys. Soc. (London)*, Sec. B, 68, No. 7, 400-407 (1955) July 1.

Study of wear mechanism using a radioactive annealed steel pin which is rubbed against a hardened steel ring; a layer of transferred matter from the pin on to the ring oxide and this oxide is then worn away as debris.—BNF. 10816

3.5.8

Influence of Stress Conditions on Corrosion Fatigue Strength. T. NISHIHARA AND K. ENDO, *J. Japan Soc. Testing Materials*, 4, No. 21, 154-159 (1955) Mar.

In order to utilize the data on corrosion fatigue tests correlation of corrosion fatigue strengths under various stress conditions is studied. The reduction rate of fatigue strength due to corrosion, β_c , is compared under alternating bending and torsional stresses. Under similar test conditions β_c in torsion is found lower than in bending and the relation of both values is explained using authors' criterion on fatigue failures. Further, the effect of simultaneous notch and corrosion, $\beta_{c\alpha}$, on fatigue strength is studied by means of varying sharpness of circumferential notches of rotating bending test pieces. $\beta_{c\alpha}$ becomes less than $\beta_c \times \beta_\alpha$ with sharpening of notches.—JSPS. 10873

156a

3.5.8, 3.5.3, 1.6

Ultrasonic Engineering: with Particular Reference to High Power Applications. A. E. CRAWFORD. Book, 1955, 344 pp. Butterworths Scientific Publications, London.

Theory of ultrasonics and nature and mechanism of cavitation in liquids including cavitation erosion; detailed survey of generators and transducers and auxiliary apparatus including the necessary theory; the section on applications includes Metallurgical Applications (pp. 230-256) and Coatings of Metals (pp. 257-285) and discusses molten metals, degassing, grain refinement, segregation, incorporation of metal and non-metals into melt, drilling, soldering and tinning; short mention of thickness measurement and flaw detection.—BNF. 10757

3.5.8, 3.5.9, 4.6.1, 1.6

Investigation of Stress-Corrosion of Austenitic Stainless Steels and Other Materials in High Temperature Water Environments. Summary of Work From January, 1951 to January, 1955. W. LEE WILLIAMS. U. S. Naval Engineering Experiment Station Rept. EES-040028K, March 29, 1955, 88 pp.

Data are summarized from an investigation of the stress corrosion behavior of various constructional materials in high-temperature water. Data are presented on the behavior of austenitic stainless steels, martensitic and ferritic stainless steels, nickel base alloys and a few miscellaneous materials. The principal variables studied included alloy composition, stress level, water composition, liquid versus vapor exposure and stress-corrosion inhibitors. Data are presented on both laboratory tests and experiments with actual equipment.—NSA. 10337

3.5.8, 3.7.3

Fretting Corrosion on a Screwed Joint Under Prolonged Fatigue Loading. J. E. FIELD, *Engineer*, 200, 301-303 (1955) August 26.

Tests on the reduction of the inherent fatigue resistance of a part subject to fluctuating stresses by fretting corrosion. Photographs, diagrams, table.—BTR. 10527

3.5.8, 3.7.3

Fatigue Aspects in Aircraft Welding Design. J. KOZIARSKI, *Welding J.*, 34, No. 5, 446-458 (1955) May.

Discusses problem of fatigue in welded aircraft structures and suggests precautions for reducing risk of fatigue failure. Residual stresses and their effect on fatigue of welds; stress concentration (structural rigidity, shear vs. tension, reinforcement, edge width, notches); resonance; properties of material (ductility, strength of weakest part of metal structure, alloy homogeneity and notch-sensitive alloys); corrosion fatigue; improvement in fatigue life and brazing of parts. 77 references.—BNF. 10435

3.5.8, 5.7.9

Uses of Vibrational Waves in Metallurgical and Mineral Dressing Processes. J. K. ALMOND, *Metal Treatment & Drop Forging*, 22, No. 122, 475-480, 484 (1955) Nov.

Applications of vibrations in industry include flaw-detection machines, fatigue testing, tinning of metals, ultrasonic machining and powder production and comminution. Effects on metal melts are considered. In mineral dressing operations, vibrational waves are applied

in jigging and tabling, classification and flotation. Attempts have been made to utilize dispersive and coagulative properties of vibrations in thickening, fume precipitation and emulsification. Vibrational waves are also used to prevent formation of scale in boilers and assist in fluidization. Other instrumental applications are mentioned. 46 references.—INCO. 10715

3.5.8, 6.3.6, 6.3.11

The Problem of Stress Corrosion of Homogeneous Solid Solutions. Part III. Dependence of Stress-Corrosion Sensitivity in Solid Copper—Gold and Silver—Gold Solutions on the Gold Content and Relationship to the Solid Solution Effect. (In German.) LUDWIG GRAF AND JURGEN BUDKE, *Z. Metallkunde*, 46, No. 5, 378-385 (1955) May.

Effect of aqua regia, potassium cyanide solution, reagents which do not attack silver and mercury on stress corrosion of above solid solutions and on the change of strength properties under the influence of a liquid metal and chemical reagents. Graphs, tables, 20 references.—BTR. 10576

3.5.8, 6.3.11

Stress Corrosion Cracking of a Gold Wedding Ring: Topic of the Month. F. M. REINHART, *Corrosion*, 11, No. 12, 503t-504t (1955) Dec.

Low karat gold alloy (43.5 copper, 12.3 silver, <0.1 nickel, 5.2 zinc, balance gold) recently unearthed in a garden was found to be brittle and cracked in many places. Cracks were caused by stress corrosion. This condition probably resulted from presence of residual internal stresses which were combined with perspiration of wearer or with garden fertilizer, or both. Photomicrograph.—INCO. 10870

3.5.8, 7.3

How Corrosion Causes Fatigue Failures. W. G. DUDLEY AND J. J. MCKETTA, *Petroleum Refiner*, 34, No. 10, 141-142 (1955) October.

Mechanism of corrosion fatigue, occurrence and methods of preventing such corrosion fatigue in petroleum sucker rods, drill collars and pump shafts are briefly discussed. Stress versus log of time is plotted for fatigue with and without corrosion.—INCO. 10750

3.5.9

Metals for Short Time Service at High Temperatures: Materials & Methods Manual No. 115. A. LEVY, *Materials & Methods*, 41, No. 4, 117-132 (1955) April.

Explains problems in selection of materials for service conditions in aircraft power plants and rockets. Iron-, nickel- and cobalt-base alloys: high-temperature properties (short-time tensile, creep, stress-rupture, physical properties); fabrication characteristics; scaling and corrosion characteristics; elevated temperature limitations of metals; applications in turbojet afterburners, ramjet engines and rockets.—BNF. 10444

3.5.9

Alloys for Use at High Temperatures. W. BETTERIDGE, *Brit. J. Applied Physics*, 6, No. 9, 301-306 (1955) Sept.

Corrosion resistance and high strength at elevated temperatures are discussed with reference mainly to various iron-chromium-nickel alloys, including nickel-chromium with small additions of calcium, cerium, zirconium, thorium, silicon;

iron-20/25 chromium-4/6 aluminum and Nimonic 95.—BNF. 10684

3.5.9

Development of High-Strength, High-Temperature Materials. K. BUNGARDT. *Stahl und Eisen*, 75, 1383-1389 (1955) October 20.

Most important currently available high-temperature materials comprise austenitic nickel-chromium steels, nickel-chromium-cobalt-iron alloys, nickel- and cobalt-base alloys with face-centered cubic mixed crystal structure with further alloying additions for formation of carbides, nitrides, inter-metallic compounds, ordered phases, etc. Mechanical properties of representative types of these classes of materials, present trend of development, effect of alloying additions, high-melting point metals and cermets, and possible use of graphite as high-temperature material are discussed.—INCO. 10743

3.5.9, 1.6

Utilization of Heat Resistant Alloys. Book, 1954, 288 pp. American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio.

Papers presented at symposium, March, 1954, in honor of Prof. A. E. White, the first President of the American Society for Metals, including: Creep and Fracture at Elevated Temperatures, N. J. Grant (pp. 1-28); Factors Involved in Using High Temperature Test Data for Selecting Materials and Proportioning Parts, C. L. Clark (pp. 29-54); Alloys and Their Properties for Elevated Temperature Service, H. C. Cross and W. F. Simmons (pp. 55-96); Stress Calculations for Design for Creep Conditions, P. F. Chenea (pp. 97-105); Engineering Practice for Selecting Materials and Proportioning Components Operating at High Temperatures in the Steam Power Industry, H. A. Wagner and J. A. Bleckie (pp. 106-121); Criteria in the Selection of Materials for Aircraft Gas-Turbines, H. Hanink and L. Luini (pp. 122-147); Production and Fabrication of Heat Resistant Alloys from the Producers' Viewpoint, C. T. Evans, Jr. (pp. 148-183); Fabrication of High Temperature Alloy Steel Piping Suitable for Central Station and Oil Refinery Service, R. W. Emerson (pp. 184-218); Jets: from Blueprint to Engines, W. E. Jones and A. J. Rosenberg (pp. 219-243); Metallurgical Variables Influencing Properties of Heat Resistant Alloys, J. W. Freeman, C. L. Corey and A. I. Rush (pp. 244-265); Development of and Acceptance Testing Procedures Against Specifications, A. W. F. Green (pp. 266-271). Also contains chronological list of the publications of A. E. White, compiled by B. A. Uhlendorf (pp. 272-288).—BNF. 10634

3.5.9, 4.3.3

Technical Problems of Vanadium Pentoxide. (In German.) K. KONOPICKY. *Brennstoff-Chem.*, 36, No. 9/10, 151-155 (1955) May 11.

Effect of vanadium pentoxide on furnace linings and metal parts. Graphs, tables, photographs. 63 references.—BTR. 10443

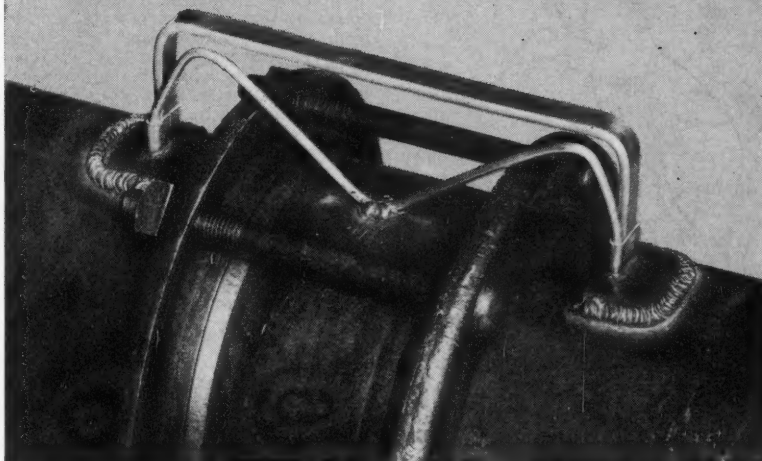
3.5.9, 6.2.2

The Oxidation of Iron-Nickel Alloys. R. T. FOLEY, J. U. DRUCK AND R. E. FAYELL. *J. Electrochem. Soc.*, 102, 440-445 (1955) August.

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dation of iron-nickel (42 percent nickel) alloy. Reaction products were examined by metallographic and electron diffraction techniques, as well as chemical analyses after stripping. Tables, graph, micrographs. 13 references.—BTR.

10506

3.5.9, 6.2.2

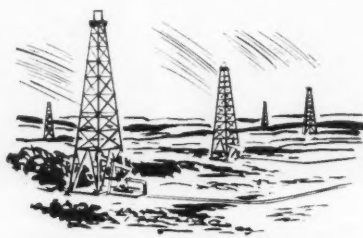
Thermal Shock: Some Experiments with Cast Iron. E. B. EVANS. *J. Research & Development, Brit. Cast Iron Research Assoc.*, 5, No. 12, 643-654 (1955) June.

Major cracking can be caused in cast iron components subjected to thermal shock, but the propagation of cracks is governed by design of component. Cracking can occur in re-entrant angles or where there are abrupt changes of section. Laboratory test pieces can be used to reproduce thermal shock cracking and a cylindrical specimen with a pattern of holes giving various section thicknesses is particularly suitable. Using this type of test piece to study effects of variations of composition on resistance to thermal shock, the following facts were noted. Resistance to thermal shock is markedly reduced when phosphorus is increased from 0.05-1.4, decreased slightly when carbon increased from 2.99-3.66 percent, and increased as silicon is increased from 1.3-3 percent. Ingot mold irons have better resistance to thermal shock than gray irons of finer graphite structure. Nodular irons have the best resistance. Two cerium-treated and two nickel-magnesium-treated irons were used.—INCO.

10517

3.5.9, 6.5

High-Temperature Oxidation-Resistance of Steels and Alloys. L. COLOMBIER.



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Metaux. Corrosion-Industries, 30, No. 359/360, 294-303 (1955) July-August.

Notes on resistance to oxidation of chromium-iron alloys, aluminum-chromium-iron alloys, chromium-silicon steels, nickel-chromium alloys, nickel-chromium stainless steels and nickel-chromium-iron alloys. Additional information is given on resistance to nitrogen, hydrogen, sulfur compounds, combustion gases, molten metals of the above materials. Effect of cerium and calcium additions on oxidation resistance of nickel-chromium and nickel-chromium-iron alloys is discussed.—INCO.

10724

3.5.9, 7.1

Experimental High-Temperature Materials for Gas Turbines. A. R. EDWARDS. Paper before Australian Inst. Metals, 8th Ann. Conf., Adelaide, April 21, 1955. *Australasian Engr.*, 1955, 50-55, July 7.

Discusses cermet, molybdenum and its alloys and alloys of chromium as high temperature gas turbine materials. Oxidation resistance of nickel-titanium carbide or cobalt-titanium carbide cermet is improved by addition of tantalum carbide and columbium carbide. Cladding with stainless steel or nickel alloys shows promise as means of overcoming scaling of molybdenum alloys. Advantages of chromium as basis metal include high interatomic and intergranular cohesion providing creep resistance, classification as a non-strategic material and high resistance to oxidation at high temperatures. Production of pure chromium by electrolysis, constitution of chromium alloys, high-temperature and ordinary temperature properties are reviewed.—INCO

10751

3.6 Electrochemical Effects

3.6.2, 2.3.5

Corrosion. M. G. FONTANA. *Ind. & Eng. Chem.*, 47, No. 11, 81A-82A, 84A (1955) November.

Describes mechanism of concentration cell corrosion, occurrence of such corrosion (also called crevice corrosion and deposit attack) and procedures for concentration cell tests. These include oxygen concentration cell for laboratory investigations, plant test rack, bolted disks, rods and hairpin bend specimens.—INCO.

10792

3.6.5, 6.5

Electrode Potentials of Ternary Alloys Containing Intermetallic Compounds. (In Russian.) V. A. IURKOV AND M. A. KRISHTAL. *J. Phys. Chem., USSR (Zhur. Fiz. Khim.)*, 29, No. 5, 778-780 (1955) May.

Measurements of electrode potentials of alloys provide data for predicting corrosion behavior. Micrographs, graph. 6 references.—BTR.

10424

3.6.5, 3.8.4, 3.8.2

The Positive Difference Effect. (In Russian.) A. F. BOGOYAVLENSKY AND L. N. UMova. *J. Applied Chem., USSR (Zhur. Priklad. Khim.)*, 27, No. 5, 548-551 (1954) May.

Cf. Tomashev, *J. Phys. Chem., USSR (Zhur. Fiz. Khim.)*, 12, 412 (1938). The positive difference effect, Δp , is the reduction in the action of the weak cathodes of local elements on the introduction of a new strong cathode and is of interest in studying corrosion processes. Bogoyavlensky and Umova have determined the values of Δp for short-circuited zinc/platinum couples in hydro-

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chloric acid solution. ΔV (measured as the difference in the volume of hydrogen liberated, in cc) varied linearly with the acid concentration C , the empirical coefficient in the equation $\Delta V = \alpha + \beta C$, being $\alpha = 0.04$ and $\beta = 1.6$ when C was expressed in normalities. ΔV also varied linearly with the ratio of cathodic and anodic surfaces ($\Delta V = a + b \cdot S_k/S_a$), provided that $S_k/S_a > 1$; the constants were $a = 0.042$ and $b = 0.093$. α and a are identical and represent the value of ΔV in distilled water. A linear relation was not observed with $S_k/S_a < 1$; as the ratio was reduced further ΔV increased, then became constant at $S_k/S_a < 1/4$. ΔV did not depend on the distance between the electrodes, using 0.2N-HCl. The stimulating action of an external cathode (platinum) is connected with the transformation of microanodes of the electrode into microcathodes.—MA. 10657

3.6.5, 3.8.4, 4.7

Electrode Potentials of Metals in Molten Salts. (In Russian.) Yu. K. DELIMARSKY. J. Phys. Chem., USSR (*Zhur. Fiz. Khim.*), 29, No. 1, 28-38 (1955).

Electrode potentials of various metals were calculated on the basis of decomposition potentials of a number of molten electrolytes, assuming the electrode potential of sodium in its pure molten salt to be zero. The electrode potentials of some metals were determined experimentally, using the tin-sodium/glass reference electrode and were found to be in good agreement with the calculated values. In all determinations the standard state of the reference electrode was defined as that in which the sodium electrode in the half-cell tin-sodium/glass, Na⁺/molten electrolyte containing Na⁺, is in equilibrium with its pure salt, for which 100 percent dissociation can be assumed. On the basis of the electrode potentials obtained, electrochemical series of metals were constructed for molten chlorides, bromides and iodides of metals, for sodium iodide and sodium nitrate and for seven binary and one ternary electrolytes. The sequence of metals in these series was different for different electrolytes and varied with temperature for the same electrolyte. The electrode potentials depended also on the chemical interaction between the components of the molten electrolyte. The electrode potentials of heavy metals (thallium, manganese, zinc, cadmium, silver, copper, etc.) were more negative in molten iodides than in bromides, or than in chlorides. Light metals, with the exception of lithium, did not obey this rule. On the contrary, in the case of aluminum and magnesium the potentials became more positive when passing from chlorides to iodides. The influence of anions on the electrode potentials was explained by the change in the degree of dissociation and also by the mutual polarization and deformation of ions in the electrolyte.—MA. 10764

3.6.5, 6.2.2, 6.2.3, 3.8.2

Dissolution of Metals in Aqueous Acid Solutions. Part I. Current-Potential Relations for Iron and Mild Steel. A. C. MAKRIDES, N. M. KOMODROMOS and NORMAN HACKERMANN. J. Electrochem. Soc., 102, 363-369 (1955) July.

Measurements of electrode potentials of iron in hydrochloric acid alone and in hydrochloric acid solutions containing depolarizers are discussed on the basis of the theory of mixed-potential. Graphs. 18 references.—BTR. 10568



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3.6.6

Protection of Bimetallic Junctions. A. G. WILKIE. *Corrosion Technology*, 2, No. 5, 156 (1955) May.

Bimetallic junctions met in practice are principally those between aluminum or magnesium alloys and iron or steel members. Much can be done in the methods of fabrication to minimize the risk of bimetallic corrosion such as avoidance of crevices and moisture traps. Anode metals should be as large as possible in relation to cathodic metal in order to spread anodic attack around areas of contact. Where subjected to moisture, an insertion medium is required. It is also desirable that the insertion should incorporate an inhibitor. Proprietary impregnated and coated tape based on petrolatum with metallic chromate inhibitor is also available.—INCO. 10339

3.7 Metallurgical Effects

3.7.3, 7.7

Bolted Connections in Aluminium Busbars: A Review of Experience, with Recommendations. J. C. BAILEY. *Engineer*, 199, 551-554 (1955) April 22.

Reviews laboratory work and practical experience over the past 30 years. Relation between clamping pressure and contact resistance; effect of surface preparation; theory of contact resistance; installations in an aluminum reduction plant, substations and telephone exchanges; jointing recommendations (including method of protection against corrosion, and reassembly).—BNF. 10468

3.7.4

Effects of Impurities and Imperfec-

tions on Mechanical Properties. E. R. PARKER AND J. WASHBURN. Paper before Seminar on Impurities and Imperfections 36th Nat. Metal Congress & Exposition, Sponsored by Am. Soc. Metals, Chicago, Oct. 30-Nov. 5, 1955. American Society for Metals, Impurities and Imperfections, 1955, 145-161.

Study of dislocation networks and effects of such networks upon the mechanical behavior of both single and polycrystalline metals. Fundamental processes involved in work hardening and creep and main features of yield point phenomenon are discussed. Graph shows effect of small angle boundaries developed within grains of polycrystalline nickel (by a prestrain and anneal treatment) on stress-strain curve. Shape of creep curve has been controlled by introducing controlled substructures in creep specimens. Results for high purity polycrystalline nickel are shown. Increasing yield point of mild steel (AISI 1020) by means of a substructure introduced under carefully controlled conditions is described. Graphs, 14 references.—INCO. 10845

3.7.3, 8.8.5

Added Life for Brazing Fixtures. C. EMERY AND P. GOETCHEUS. *Steel*, 136, No. 26, 82-83 (1955) June 27.

By integrating design with required properties of the alloy, designer can increase service life of fixtures and furnace trays and frequently reduce materials costs. Primary factors to be considered in selection of heat-resisting alloys are tensile strength, creep strength, corrosion resistance, thermal expansion, thermal and mechanical shock, stability and cost. Alloy steels acceptable for brazing applications including 330 (35 nickel, 15%

chromium), 310 (25 chromium, 20% nickel), 309 (25 chromium, 12% nickel), 430 (17% chromium) and 446 (27% chromium) are evaluated in a table. Satisfactory microstructure of heat-resisting alloy is shown. Illustrations.—INCO. 10059

3.7.3, 3.5.9

New Heat Resistant Adhesives for Metal Bonding. G. EPSTEIN. *Materials & Methods*, 41, No. 1, 107-110 (1955) January.

Two heat resistant adhesives suitable for structural applications at 600 degrees F were developed by N. Am. Avia., Inc. First, NAA Hi-Temp, is used for metal-to-metal adhesive bonding. Second, CHT, is a modification designed for fabrication of heat resistant sandwich constructions. Surface preparation, adhesive application, and curing are covered. Tensile-shear properties of NAA Hi-Temp adhesive bonds on a number of materials, including aluminum, 2024-T3 clad, titanium, RC-130A, stainless steel 17-7 and 18-8 and a glass-reinforced plastic laminate, are tabulated.—INCO. 10063

3.7.4, 3.7.3, 6.2.5

Dehomogenization of Solid Solutions. L. COLOMBIER. *Metal Progress*, 67, No. 116-117 (1955) Feb.

Spontaneous segregation of certain constituents of alloys in grain boundaries is advanced as a theory to explain phenomena of overheating and temper brittleness in a nickel-chromium-molybdenum steel quenched after over-heating at 2280-2370 degrees F and in several similar cases as well as numerous observations in other fields. Overheating and temper brittleness are explained by retention of austenitic grain boundaries in the martensite, resulting in the steel having a "double structure" that consists of a persistent network of austenitic boundaries superposed on martensitic structure. White decarburized zones, observed along boundaries of a carburized 18-8 stainless steel (0.6% carbon) heated to 2280 degrees F, water quenched and tempered at 1380 degrees F to induce carbide precipitation, are shown in a photomicrograph. Carbide segregation in grain boundaries provides explanation for susceptibility of this type of steel to intergranular corrosion.—INCO. 9961

3.7.4

Contribution of Crystal Structure to the Hardness of Metals. W. CHURB. *J. Metals* (Trans. AIME), 7, No. 1, Section 2, 189-192 (1955) Jan.

Measurements of hardness just above and below allotropic change points show that structure affects hardness. DPH of cobalt, iron, titanium, uranium and zirconium measured up to 1000 degrees C. Body-centered cubic is always the softer structure when it is involved in an allotropic transformation. Close-packed and more complex structures are inherently harder and hence may be expected to be better basis materials for high-strength alloys.—BNF. 9940

3.8 Miscellaneous Principles

3.8.4, 3.7.4, 5.3.4

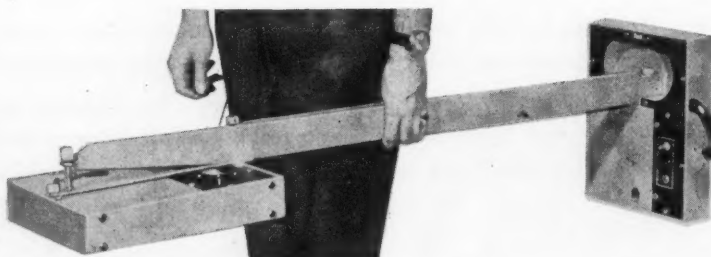
The Kirkendall Effect in Metals. K. SACHS. *Metal Treatment*, 22, No. 114, 119-125 (1955) March.

Mechanism of Kirkendall diffusion effect and its relation to properties of metals, i.e., formation of voids, porosity and micropores, dislocations, healing of

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3.8.4, 4.7, 6.3.10

Kinetics of Nickel-Sulphur and Steel-Sulphur Reactions. A. DRAVNIKS. *J. Electrochem. Soc.*, **102**, No. 8, 435-439 (1955) August.

Measurement of the rates of corrosion of A-nickel (99.4 percent) in molten sulfur at 205-445°C and relation to the nickel-sulfur phase diagram.—BNF. 10748

3.8.4, 6.3.6, 3.4.6

The Copper Fluorides. Part I. X-Ray and Electron Microscope Examination. J. M. CRABTREE, C. S. LEES AND K. LITTLE. Atomic Energy Research Establishment, Harwell, Berks, England. *J. Inorg. and Nuclear Chem.*, **1**, 213-217 (1955) June.

X-ray diffraction powder photographs have been used to study the fluorides of copper. Both anhydrous cupric fluoride and the dihydrate are slowly converted into a green basic fluoride in atmospheric air. In addition, one other basic fluoride has been observed which is unstable in air. No trace of any compound which might be cuprous fluoride has been obtained, in spite of numerous attempts to make it. Electron diffraction and electron microscope photographs of the corrosion film formed by the action of elementary fluorine on copper at temperatures between 100 and 500°C have been taken. There is good evidence that the film has a cupric fluoride structure rapidly changing to the basic fluoride on exposure to air. Electron microscope investigations show that copper metal can migrate and crystallize as bulk copper at temperatures as low as 300°C. (auth).—NSA. 10735

3.8.4, 6.3.10

The Initial Oxidation of Nickel. URSULA M. MARTIUS. *Can. J. Phys.*, **33**, 466-472 (1955) August.

Specific features of the oxidation of grain boundaries; tentative explanation of the observed phenomena. Micrographs. 9 references.—BTR. 10564

3.8.4, 6.3.17, 4.3.5

Reaction of Nitrogen with Uranium. M. W. MALLETT AND A. F. GERDS. *J. Electrochem. Soc.*, **102**, 292-296 (1955) June.

Rates of reaction of nitrogen with uranium were determined by volumetric measurements in the temperature range 550 to 900°C at atmospheric pressure. The reactions were found to follow a parabolic rate law with some deviations initially and also after the period of parabolic reaction. Surface reaction products formed in the temperature range 550 to 750°C were identified by x-ray diffraction studies to consist principally of UN_2 with slight evidence of U_2N_3 in some cases. Between 775 and 900°C the three nitrides UN , U_2N_3 , and UN_2 were found in the surface reaction product. The parabolic rate constant for the reaction between 550 and 750°C was found to be $k = 202 \exp(-25,500/RT)$ (ml/cm²)^{1/2}/sec. The activation energy, 25,500 cal/mole, has a probable error of ± 1800 cal/mole. Between 775 and 900°C the parabolic rate constant is $k = 3.95 \exp(-15,100/RT)$ (ml/cm²)^{1/2}/sec., where $15,100 \pm 2000$ cal/mole is the energy of activation. It has not been determined if the change in rate constant near the temperature of

the beta to gamma transformation in uranium has any special significance. (auth).—NSA. 10569

3.8.4, 6.3.19

Diffusion of Zinc in Crystalline Zinc Oxide. E. A. SECCO AND W. J. MOORE. *J. Chem. Phys.*, **23**, 1170-1171 (1955) June.

The diffusion of zinc in crystals of zinc oxide has been measured from 900 to 1025°C in an atmosphere of zinc vapor. At 1 atm zinc pressure, it was found that $D = 4.8 \exp(-73 \text{ kcal/RT}) \text{ cm}^2 \text{ sec}^{-1}$. (auth).—NSA. 10408

3.8.4, 6.3.21

Preparation (and Properties) of Actinium Metal. JOSEPH G. STITES, JR., MURRELL L. SALUTSKY AND BOB D. STONE. *J.*

Am. Chem. Soc., **77**, No. 1, 237-240 (1955).

Actinium metal in the form of small pellets adhering to the bottom of the microcrucible was obtained in mg. quantity by reduction of actinium fluoride with lithium vapor in vacuo. The melting point observed ($1050 \pm 50^\circ\text{C}$) lies between those of radium and thorium and shows both horizontal and vertical relationships with the melting points of adjacent metals in the Periodic Table. The metal resembles lanthanum in appearance and, like lanthanum, is very active chemically, oxidizing rapidly in moist air to form a white oxide which somewhat inhibits further oxidation.—MA. 10355

3.8.4, 6.4.4

The Kinetics of the Underwater Cor-

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rosion of Powdered Magnesium. E. S. FREEMAN AND S. GORDON. Paper before Am. Chem. Soc., Div. Phys. & Inorg. Chem., Mtg-in-Miniature, February, 1954. *J. Phys. Chem.*, 59, No. 10, 1009-1015 (1955) October.

Underwater corrosion of atomized and ground magnesium powder was investigated in presence of nitrogen, helium, carbon dioxide, hydrogen and oxygen. Course of reaction was followed by observing changes in volume and pressure due to hydrogen formed, as a function of time. Factors such as pH, nature of film coating the particles, specific surface, gaseous atmosphere, pressure and temperature affect rate process. Kinetics are determined by 2 rate-controlling mechanisms: a non-diffusion controlled mechanism which may involve the neutralization of protons or the combination of hydrogen atoms on the surface of the metal to

form molecular hydrogen; and the diffusion of water through the hydrated magnesium hydroxide film coating the metal particles. Former mechanism predominates during initial stages of reaction; whereas the latter is important when films of sufficient thickness are formed.—INCO. 10765

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.1, 3, 3.4

Corrosion Aspects of Air Pollution. LEONARD GREENBURG AND NORRIS B. JACOBS. *Am. Paint J.*, 39, 64+ 7 pages (1955) July 11.

Classification of atmospheres and their active corrosive agents; types of materials affected and their relative degree of

resistance; effects of climatic conditions; bacterial deterioration. Tables, 15 references.—MR. 10572

4.2.3

The Effect of Hydrochloric Acid on the Corrosive Nature of Combustion Gases Containing Sulphur Trioxide. R. W. KEAR. *J. Applied Chem.*, 5, 237-242 (1955) May.

Mild steel probes studied from 27 to 150°C; a corrosion peak exists between water and acid dew-points. Acid and chlorine increase corrosion. Graphs, diagrams, 7 references.—BTR. 10421

4.2.3

Further Investigations Into the Corrosion of a Steel Surface by Condensed Films of Sulphuric Acid. R. W. KEAR. *J. Applied Chem.*, 5, No. 6, 260-266 (1955) June.

Following previous studies of the corrosion of cooled steel probes by flue gases containing sulfur dioxide and sulfur trioxide further experiments show that for tests up to 24 hours there is a reduction in rate of corrosion after eight hours and in the presence of corrosion products the corrosion continues even when the metal temperature is raised to or above the acid dewpoint temperature. Mechanism is discussed. 10 references.—INCO. 10422

4.2.3

The Corrosive Nature of Combustion Gases From Carbon Monoxide Flames Containing Sulphur Oxides. G. WHITTINGHAM. *J. Applied Chem.*, 5, 316-322 (1955) July.

Mild steel corrosion was at a maximum from 66 to 70°C and combustion air humidity had a significant effect. Tables, graphs, diagrams. 15 references.—BTR. 10328

4.2.3

Low-Temperature Corrosion by Flue-Gas Condensates. R. W. KEAR. British Coal Utilisation Research Association, *Monthly Bulletin*, 19, 297-318 (1955) July.

Components, other than sulfur, that make a significant contribution to normal flue gas corrosion are hydrochloric acid and oxides of nitrogen. Tables, graphs. 139 references.—BTR. 10807

4.2.3, 7.4.1

Economizers Can Resist Corrosion. F. B. E. HARE. *Modern Power & Eng.*, 49, No. 9, 73-76 (1955) Sept.

Economizer and air-heater corrosion is attributed to very small amounts of sulfur trioxide which combine with moisture in gas at temperatures up to 620°F to form sulfuric acid vapor of high concentration. Sulfur content of fuel, formation of sulfur trioxide acid in the gases, acid dew-point and condensation are discussed. Charts show distinguishable physical states of sulfuric acid at varied distances from the metal, positions and variations of acid dew point, rate of condensation of sulfuric acid and dissolution of mild steel and cast iron in sulfuric acid. Photograph shows band corrosion on a section of cast iron finned economizer tube, illustrating effect of load-cycle.—INCO. 10777

4.2.7

Corrosion and Meteorology. P. A. CARTWRIGHT AND J. C. HUDSON. *Nature*, 176, No. 4485, 748-749 (1955) October 15.

In studies of corrosion under tropical conditions, average yearly conditions of temperature and humidity are usually quoted. Cartwright presents an analysis



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Tensile Strength (thousand psi)....	50	65	85	45	60	40	50	35	40	25	30
Yield Strength (thousand psi).....	22	40	55	20	30	20	30	20	25	18	22
Elongation, % in 2".....	40	10	10	30	8	15	5	10	2	5	2
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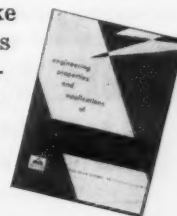
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of relative humidity for each month in Singapore and shows that average figures do not take into account the time of exposure to maximum and minimum conditions. Based on work by Vernon showing that critical humidity for iron lies between 70-80 percent, Hudson presents diagrams showing periods of the day, averaged for each month of the year, during which relative humidity of atmosphere of Kew, Singapore and Pittsburgh lies below, between, or above these limits. Importance of air pollution, especially by sulfur, is considered.—INCO. 10729

4.2.7, 2.2.2

Corrosion of Metals in the Tropics. H. R. AMBLER AND A. A. J. BAIN. *J. Applied Chem.*, 5, 437-467 (1955) Sept. The atmospheric corrosion of a few

common metals was studied at more than 20 sites in Nigeria and at some others under various conditions of atmospheric humidity and salinity. Contrary to general belief, corrosion is not generally greater under tropical conditions than in temperate climates. Map, tables, photographs, graphs. 10 references.—BTR. 10712

4.2.7, 5.6.1, 7.7

Corrosion in Singapore—Problems of Packaging and Storage in the Tropics. P. A. CARTWRIGHT. *Corrosion Technology*, 2, No. 11, 362-365 (1955) November.

Discusses general factors of climate in relation to atmospheric corrosion applicable to all tropical areas, i.e., temperature, humidity, sun temperature and presence of gases and solids in atmosphere (oxides of nitrogen formed during

thunderstorms). Author shows that, from the corrosion viewpoint, simple average figures are of little use, as a few extra degrees rise in temperature and an increase in relative humidity represent an acceleration in corrosion rate. Fungus and mold growth are discussed. Problems encountered and corrosion prevention measures in packaging materials for tropical areas are considered. Particular attention is paid to radio equipment with its many metal-to-metal contacts and organic materials. Tables, 18 references.—INCO. 10733

4.3 Chemicals, Inorganic

4.3.2, 6.2.5, 6.3.10

The Corrosion of Alloyed Steels and Nickel Alloys by Phosphoric Acid. (In German.) JOH. BUNGER. *Werkstoffe u. Korrosion*, 6, No. 8/9, 369-374 (1955) August-September.

Investigations on corrosive effects of phosphoric acid on high alloyed steels (including nickel-chromium stainless) and nickel alloys (nickel-chromium-molybdenum-copper, nickel-molybdenum-iron, nickel-molybdenum-chromium, nickel-molybdenum and nickel-silicon-copper) were carried out over a wide range of concentration and temperature. Data are given in charts. At high temperatures and concentrations, corrosion by phosphoric acid is so great that the nickel-molybdenum (70-30) alloy only is practically unaffected. Below 100°C there are wide areas of excellent or even absolute resistance to corrosion for many materials. Above 100°C, some molybdenum- and copper-containing chromium-nickel steels are fairly resistant even up to high temperatures. 9 references.—INCO. 10497

4.3.3

Nitrogen Tetroxide. E. D. CRITTENDEN AND T. J. MCGONIGLE. *Allied Chem. & Dye Corp. Aero Digest*, 71, No. 1, 60, 62, 64 (1955) July.

Large tonnage production of rocket bi-propellants through use of mixed oxides of nitrogen (MON) is discussed. Mixture of about 70 percent nitrogen peroxide and 30 percent nitric oxide offers high stability and density, good corrosion resistance, low freezing point and low vapor pressure. Carbon steel, stainless steels, aluminum, nickel and Inconel are among materials suitable for handling and storing nitrogen peroxide-nitric oxide mixtures and nitrogen peroxide. Under wet conditions stainless steels resistant to about 60 percent nitric acid serve best. Good quality ceramic bodies, Pyrex and some plastic materials are satisfactory for handling these oxides in wet or dry conditions. Tables, graphs.—INCO. 10535

4.3.3

High Temperature Corrosion Rates of Several Metals with Nitric Oxide. MILTON FARBER, ALFRED J. DARNELL AND DONALD M. EHRENBERG. *J. Electrochem. Soc.*, 102, 446-453 (1955) August.

Corrosion rates were determined for iron, tantalum, tungsten, molybdenum, nickel, copper, silver and the alloys Inconel and stainless steel. Tables, diagrams, graphs. 13 references.—BTR. 10534

4.3.3, 6.3.6

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I. S. LEVINSON. *Corrosion*, 11, No. 9, 365t (1955) Sept.

When exposed to 14 percent ammonium hydroxide at 212°F, heat treated copper was superior, more severe attack was in the vapor phase. Tables, photograph.—BTR. 10651

4.3.5, 3.2.2, 2.3.4

Effects of Hydrogen at High Pressures on the Mechanical Properties of Metals. Part I. Apparatus, Procedures, and Preliminary Results. H. C. VAN NISS AND B. F. DODGE. *Chem. Eng. Progress*, 51, No. 6, 266-271 (1955) June.

Hydrogen at pressures as low as 2000 atm. can cause dangerous embrittlement of metals even at room temperature. At high temperatures also hydrogen can cause embrittlement and in addition may attack steel chemically. Probably the most suitable material for use with high-pressure hydrogen is austenitic stainless steel. (auth).—NSA. 10333

4.4 Chemicals, Organic

4.4.8

Selective Solvents for Aromatic Hydrocarbons: Oxydipropionitrile and Thiodipropionitrile. D. A. SKINNER. *Ind. & Eng. Chem.*, 47, No. 2, 222-229 (1955) Feb.

Investigation of properties of β , β' -thiodipropionitrile and β , β' -oxydipropionitrile as selective solvents for aromatic hydrocarbons in the C_6 to C_{10} range. Stability and corrosiveness of the dipropionitriles are considered. Total immersion tests of metal billets in dry solvents at 98 degrees C are summarized. Stainless steels were relatively unaffected, mild steel and aluminum, only slightly, while copper and lead are eliminated for use with solvents. Tests with metals, water and toluene at 90-100 degrees C showed that stainless steels are suitable materials to use in contact with dipropionitriles in presence of air, water and hydrocarbons. Corrosion test data are tabulated.—INCO. 9815

4.6 Water and Steam

4.6.2, 1.6, 7.4.1, 7.6.4

Steam, Its Generation and Use. Book, 1955, 624 pp. The Babcock & Wilcox Co., 161 E. 42nd Street, New York 17.

Thirty-seventh edition. Intended primarily for mechanical engineers and mechanical engineering students in the applied thermo field, book was prepared and edited by engineers and specialists of the Babcock & Wilcox Co. Each chapter is prefaced with a brief history of subject content providing the reader with the opportunity to develop an idea of advancement, problems, success of operation and desired aims of subject treated. Replete with graphs, charts, tables, illustrations and formulae the book contains excellent material on variety of subjects such as principles of combustion, fluid dynamics, utilization of waste heat, steam temperature adjustment and control, selection of steam producing equipment, research and development, nuclear power and the cyclone furnace. It contains comprehensive appendix to subject matter as well as index. 9931

4.6.2, 3.2.2, 7.6.4, 3.2.3

Action of Boiler Water on Steel—Attack by Bonded Oxygen. C. E. KAUFMAN, W. H. TRAUTMAN AND W. R. SCHNARREBERGER. Paper before ASME, Jt. Session—Jt. Research Comm. on Boiler Feedwater

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Studies and Power Div., Ann. Mtg., New York, November 29-December 4, 1953. *Trans. Am. Soc. Mech. Engrs.*, 77, No. 4, 423-430; disc., 430-432 (1955) May.

Emphasis is placed on power of water itself, in absence of dissolved oxygen, to oxidize metal, causing substantial damage under some conditions. Attack by bonded oxygen was considered as it applied to specific damage in marine desuperheaters, at a weld in a boiler tube, in a superheater and by hydrogen embrittlement in a slightly inclined screen tube. Laboratory results show that hydrogen embrittlement can be produced and controlled in carbon-steel test bombs. Power of oxygen of water to react with steel can be curbed by making both chemical and physical changes in boiler systems. Table, photomicrographs, 16 references.—INCO. 10305

4.6.2, 7.6.4

Sources of Vent Gas in a Hot Water Heating System. L. N. MONTGOMERY AND W. S. HARRIS. Paper before ASHAE, Semi-Ann. Mtg., San Francisco, June, 1955. *Heating, Piping and Air Conditioning*, 27, No. 6, 125-129 (1955) June.

Discusses tests made to determine nature of and sources of vent gases in a closed hot water heating system having an air cushion tank just above boiler. Main source of vent gas is nitrogen which is transferred from air cushion tank. Corrosion reaction which dissolves iron in water as ferrous hydroxide and releases hydrogen at iron surface is a secondary and continuing source. Oxygen in make-up water and in air cushion tank will combine chemically in a corrosion reaction, resulting in a drop in the static head of a closed system al-

though this corrosion reaction is minor from standpoint of metal consumed. Illustrations, tables.—INCO. 10609

4.6.2, 4.6.3, 4.6.10

Developments in Feed Water Treatments. J. LEICESTER. *Corrosion Prevention & Control*, 2, No. 5, 33-37 (1955) May.

Developments in production of fresh water from salt or brackish water by distillation was discussed, emphasizing the problems of scale formation. Treatment which has become the basis of present Admiralty Evaporator Compound now in use throughout H. M. Fleet is described. Belloid TD, sodium salt of di-naphthyl methane and di-sulfonic acid, is main scale preventative constituent used in present treatment. This material is a powerful anionic dispersing agent for calcium and magnesium compounds. Second constituent is sodium salt of ethylenediamine tetra-acetic acid, a sequestering agent with the trade name of Sequestrol. Examination of scale deposits formed from brine treatment with a mixture of Belloid TD and Sequestrol showed that there is no adherent bond between the inner scale and the metal heating surface in such cases. Third ingredient is a non-toxic anti-foaming compound, a poly-ethylene glycol, which in the future will most certainly be blended with the present Admiralty Evaporator Compound.—INCO. 10085

4.6.4, 1.2.2, 5.8.2

Some Economic Data on Chemical Treatment of Gulf Coast Cooling Waters. A Report of the Recirculating Cooling Water Sub-Committee of NACE Task Group T-5C-1 on Corrosion by Cooling Waters, South Central Region, J. MAXEY

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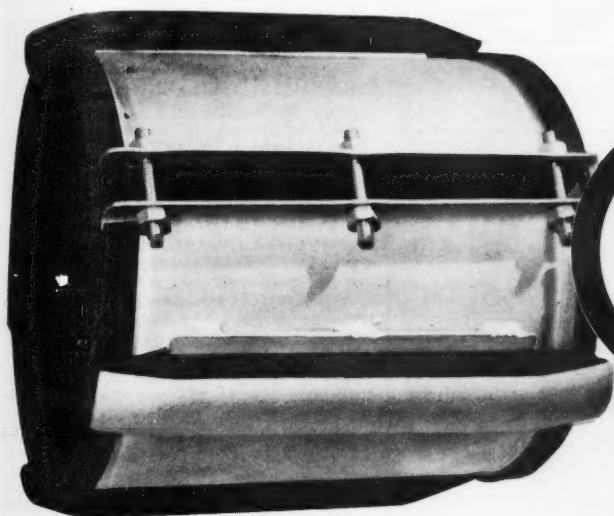
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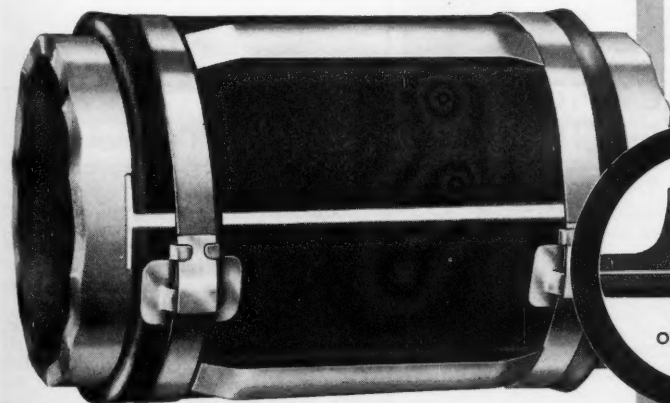
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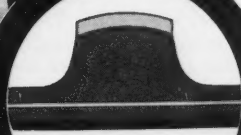
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BROOKE, Compiler. *Corrosion*, 11, No. 11, 61-63 (1955) November.

Based on the reported expenditures for inhibitors used in cooling towers of 16 Gulf Coast refineries and chemical plants, author estimates national cost of inhibitors in the chemical and refining industry to be \$22,500,000. Inhibitors are used in cooling water to regulate pH, reduce scale and corrosion and control algae. Materials used include sulfuric acid, caustic, sulfur, glucosates, sodium polyphosphate, sodium dichromate, chlorine and commercial products. Average costs of treating recirculating water on the Gulf Coast is estimated to be \$2.21 per billion BTU's. Examples of costs in the three highest and three lowest expenditures reported are given.

The committee will investigate operational and performance factors next.

10303

4.6.4, 5.8.2

Decreasing Cooling Water Corrosion. H. L. KAHLER AND C. GEORGE. W. H. and L. D. Betz Co. *Petroleum Refiner*, 34, No. 7, 144-148 (1945) July.

Pitting and tuberculation attributed to the use of anodic corrosion inhibitors can be controlled by the use of a dianodic method of treating cooling water. Dianodic method employs two anodic inhibitors—phosphate and chromate—in controlled ratio and under controlled pH conditions. Modifications of dianodic method using zinc as a supplementary treatment, either as soluble zinc, or as a zinc coating, are described. Case histories are cited to illustrate results obtainable by supplementing dianodic method with zinc. Illustrations, tables.—INCO.

10593

4.6.6

The Use of Non-Ferrous Metals in Domestic Water Supply. H. S. CAMPBELL. *Chemistry & Industry*, No. 25, 692-698 (1955) June 18.

A large part of this paper is based on publications and experience of the British Non-Ferrous Metals Research Association. Under materials for water pipes, the author discusses properties and corrosion behavior of galvanized steel, lead, copper, aluminum; buried pipes, plaster and concrete; and frost bursting. Materials considered include copper and galvanized steel for hot and cold water. Attention is also given to copper ball floats, to water fittings and to ball valve seats. Bibliography of 16 references and nine British Standards Institution specifications. Reprints will be available from BNFMA as RRA 1049P.—BNF. 10481

4.6.2, 5.7.3

Problems in Deaeration of Boiler Feedwater. H. A. GRABOWSKI, H. D. ONGMAN, W. B. WILLSEY AND W. NELSON. *Combustion*, 26, No. 9, 43-48 (1955) March.

Presents data concerning oxygen content in feedwater supplied to high-pressure boilers. Factors leading to feedwater contamination are: Introduction of underaerated condensate particularly where surge tanks float on feed pump suction or where condensate is transferred from low to high pressure system; feedwater heaters which drop to vacuum at light loads; addition of heater drips directly to condensate; addition of improperly vented evaporator vapor after cracking period; and presence of excessive turbine gland seal leaks. Since principal oxygen increase occurs in off-peak hours, test data for entire day's operation were accumulated to evaluate role of oxygen in the steam plant corrosion cycle. Graphs, 5 references.—INCO.

10001

4.6.4, 4.6.11, 7.4.1

Seawater as an Industrial Coolant. II. Equipment Experience. W. B. BROOKS. *Petroleum Refiner*, 33, 179-182 (1954) Nov.

Dow's experience at Freeport, Texas; corrosion problems. Photographs.—BTR.

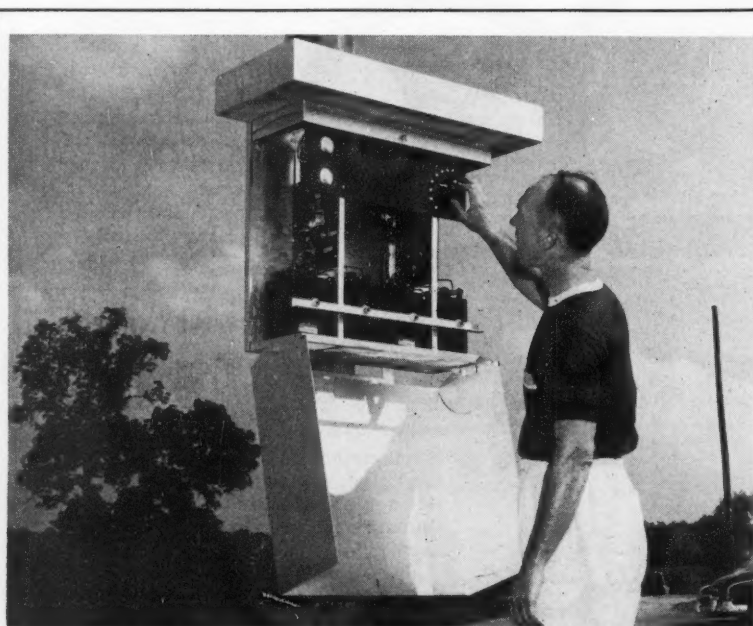
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4.7 Molten Metals and Fused Compounds

4.7, 5.8.3

Inhibitors to Transfer of Radioactive Stainless Steel Constituents in Sodium. J. W. MAUSTELLER AND S. J. RODGERS. Mine Safety Appliances Co., Callery, Pennsylvania, Contract NOs 65426, Tech. Rept. No. 41, August 24, 1955, 19 pp.

The effect of additives on the inhibition of mass transfer of radioactive stainless steel components in a sodium system has been studied. Barium was the most effective inhibitor with an inhibition effect of 17 (inhibitor effectiveness = gross count on control/gross count on sample); strontium, calcium, titanium, antimony and magnesium followed in that order. The primary inhibitor mechanism appears to be reduction of oxygen content of the sodium. Examination of wall surfaces points to a barrier coating by the inhibitor as a secondary mechanism. Ta¹⁸² and Fe⁵⁹ constituted the major activity deposited on the pipe walls. Analysis of the radioactive species deposited in titanium and antimony inhibited systems showed that



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Ta¹⁸² transfer was generally inhibited to a greater extent than Fe⁵⁹. Co⁶⁰ transfer was little affected. (auth)—NSA. 10887

4.7, 7.3

Pumps for Reactor Coolants: Products and Materials Special Report. *Nucleonics*, 13, No. 7, 78-80 (1955) July.

Lists pumps designed for leakproof operation and/or pumping of liquid metals. Tabulation is in two parts, covering mechanical and electromagnetic pumps. Manufacturer, dimensions, capacity, power required, materials and other data are included. Pump materials include 347 and 316 stainless steels, Monel, Carpenter 20, Croloy, nickel and iron.—INCO. 10833

4.7

Effects of Additives on Corrosion and Mass Transfer in Sodium Hydroxide-Nickel Systems Under Free-Convection Conditions. AMERICO F. FORESTIERI, Lewis Flight Propulsion Lab., NACA. U. S. Nat'l. Advisory Comm. Aeronaut Research Memo, E54E19, May 21, 1954, 13 pp.

Experiments were carried out under free-convection conditions in sodium hydroxide-"L" nickel systems. Nickel crucibles half full of sodium hydroxide were heated for 24 hours at 1500°F with a temperature difference of 45°F. The effect of additives such as metals, salts, oxides, and nitrides on the extent of corrosion and mass transfer was determined by measurement of the weight change of a specimen in the hot zone and by metallographic examination of the specimen cross section. Reduction in mass transfer occurred with additives of powdered chromium and aluminum.—NSA. 9445

4.8 Other

4.8, 6.2.5

Human Body Fluids Affect Stainless Steel. C. A. ZAPFE. *Metal Progress*, 68, No. 1, 95-98 (1955) July.

Mechanochemical attack is more far-reaching than previously supposed, to the extent that austenitic stainless steels have failed from stresses not exceeding residual effects of cold working and from corrosives no stronger than human perspiration and other products of physiological processes. Recent court case involved the fracture of a Type 316 collision plate 90 days after insertion while patient was in bed.—INCO. 10389

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.3

Induced Alternating Current Used for Cathodic Protection of a Coated Pipe Line. S. J. BELLASSAL. *Corrosion*, 12, No. 1, 11-31 (1956) January.

After making repairs on a leak on a coated line through a salt marsh and paralleling a high voltage high line, it was learned that although considerable gradients existed in the earth adjacent to the high line there was no correlation in the measured quantities. It had been considered that natural rectification of the induced AC voltage was occurring. After tests with coupons buried near the pipeline showed the pipeline was predominantly positive to earth at the leak location, a test ground bed was constructed to examine the feasibility of rectifying the induced alternating current. Measurement of the rectified voltage be-

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tween the pipeline and the test ground bed through a 25-ampere, 18-volt selenium rectifier was 5 volts DC available for cathodic protection. A 5-ampere, 15-volt selenium stack, ten 3-inch x 60-inch graphite rods and 500 feet of 1/0 copper cable was calculated to provide circuit resistance of the required value to protect the line cathodically. 10581

5.2.3

How General Petroleum Corp. Determines the Best Intervals for Cathodic Protection Units. V. A. BARNATO. *Oil Gas J.*, 54, No. 23, 238-240 (1955) October 10.

Proper spacing of rectifiers as determined from theoretical design data and from actual field tests and observations. Criteria of protection used is the simple measurement of pipe-to-soil potential where minimum point of protection is held to 850 mv. negative to a copper sulfate electrode and maximum point of protection on coated sections is potential of 2.0 negative. Problem is considered under conditions where there is no interference from foreign pipelines and where foreign pipelines are so located as to cause interference. Graphs.—INCO. 10707

5.2.3

Anodes Installed by Jetting. M. E. PARKER. *Pipe Line News*, 27, No. 4, 57 (1955) April.

Installation of a high-silicon cast iron anode in a stream bottom where the soil was essentially quicksand, using a truck-mounted rotary jet pump, is described. Resistances of anodes installed without backfill are discussed. 10848

5.2.3, 7.10

Cathodic Protection Installations at

Kwinana. K. A. SPENCER. *Corrosion Prevention and Control*, 2, No. 7, 23-27 (1955) July.

Cathodic protection for marine structures of Kwinana Refinery in Western Australia. Jetty is constructed of asphaltic enamel coated steel box piles with concrete muffs. To ensure electrical continuity of piles, they are bonded with 1 1/8 inch steel bar, bitumen coated and wrapped with PVC tape. Current is supplied by three graphite anode groundbeds located on shore. Jetty and associated mooring dolphins are protected by total AC power input of 12 KVA which will be reduced when calcareous deposits have built up. Protection of water intake flume is described. Diagrams, illustrations.—INCO. 10401

5.2.3, 8.4.3

'Juice' Cheaper Than Downtime. W. A. JOHNSON. *Corrosion Rectifying Co. Petroleum Processing*, 10, No. 9, 1372-1373 (1955) September.

Cathodic protection is applied with satisfactory results to buried lines and metallic structures in the petroleum plant of Southwestern Oil Refining Co. No known corrosion has occurred in the three years the system has been in service on 47 storage tanks and their interconnecting piping. Platinum anodes are used to protect heat exchangers.—INCO. 10432

5.2.4, 5.2.1

Corrosion Protection a Continuous Job. H. ALLEN. *Pipe Line Industry*, 2, No. 3, 66, 69-70, 72 (1955) March.

The use of periodic surveys to ensure continuous cathodic protection is discussed and illustrated by typical curves of pipe to soil potentials and line cur-

rents before and after deterioration or failure. 10708

5.3.1

Alloy Plating. R. T. GORE. *Product Eng.*, 26, No. 9, 136-139 (1955) Sept.

Evaluates available alloys and plating methods, properties, advantages and limitations and basic plating procedure for brass, lead-tin, lead-silver, nickel-cobalt, tin-nickel and others and discusses deposit properties, applications and plating procedure of copper-tin (bronze) alloy, a corrosion-resistant undercoating with better throwing power and higher deposition rates than copper.—INCO. 10554

5.3 Metallic Coatings

5.3.4

Cathodic Polarisation in Electrolytic Tin Plating from Chloride Electrolytes. (In Russian.) I. E. GUREVICH. *J. Applied Chem., USSR (Zhur. Prikladnoi Khimii)*, 28, No. 3, 285-290 (1955) Mar.

The greatest increase in polarization was given by additions of tetrabutylammonium iodide (other additions tried were gelatin, thymol, phenol, cresol, glue, and α -naphthol). Bright, fine-grained, compact deposits were obtained. Bath used contained stannous chloride, sodium fluoride, ammonium fluoride and hydrochloric acid.—BNF. 10820

5.3.4

Electrodeposition of Heavy Nickel. Parts I, II. D. J. FISHLOCK. *Product Finishing*, 8, Nos. 6, 7, 54-62, 110; 66-74 (1955) June, July.

Electrodeposition of heavy nickel for wear and corrosion resistant applications, i.e., salvaging of machining errors of worn or damaged parts. Design considerations, suitable equipment, bath compositions, control of solutions (rapid analysis for nickel, ammonium, fluoride and contaminants present), types of anodes, disposal of effluents, production schedules. 7 references.—BNF. 10825

5.3.4

An Experimental Investigation of the Metal Spraying Process. A. MATTING AND K. BECKER. *Electroplating and Metal Finishing*, 8, No. 3, 101-103 (1955) Mar.

Sprayed metal coatings have characteristic properties which distinguish them from the cast or wrought forms of the same material. These differences have frequently led to misapplication of the metal spraying process. A fundamental investigation to determine the properties and structure of sprayed metal coatings has been carried out at the Institute für Werkstoffkunde at the Technischen Hochschule, Hanover, and this article is the first installment of a report on the investigation and the results obtained.—ZDA. 10894

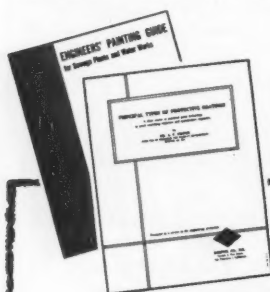
5.3.4, 2.3.7

Instrumentation in Electroplating. J. L. M. FLETCHER. *Metal Ind.*, 86, No. 25, 533-537 (1955) June 24.

Process control instruments measuring temperature, current supply, pH control and Hull Cell and quality control instruments measuring deposit thickness, porosity, microhardness and abrasion resistance, surface finish and reflectivity, adhesion and internal stress are discussed.—INCO. 10508

5.3.4, 3.5.8

How to Curb Chrome-Plate Fatigue. J. E. STARECK, E. J. SEYB AND A. C.



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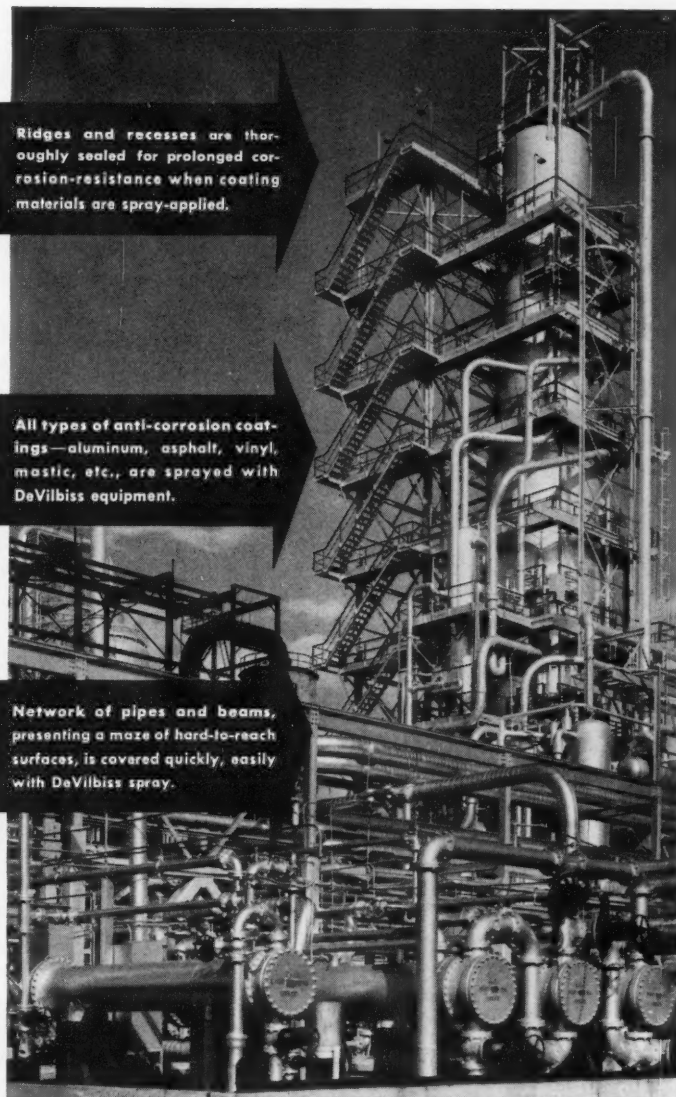
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TULMELLO. *Steel*, 137, No. 6, 82-83 (1955) August 8.

Tests with a special chromium plating bath on superstrength SAE 4140 steel gave a fatigue limit of 101,000 psi, less than 2 percent reduction of fatigue limit of unplated steel (103,000 psi). Ordinary chromium plating reduces fatigue limit as much as 50-60 percent. Stress in chromium deposit is primary factor in determining fatigue limit and stress and fatigue are related to number of crack lines in unbaked chromium deposits. Baking at 200-400F to eliminate hydrogen embrittlement is harmful and should be avoided or done at 750F. Graphs.—INCO. 10353

5.3.4, 6.6.8

Methods of Coating Plastics with Metal. J. KEATING. *Metal Finishing*, 53,

No. 9, 76-78, 85 (1955) September.

Discusses the preparation of plastics (filling of pores, cleaning and roughening), adhesion of metal layers on plastics, application of silver immersion coatings and electroplating factors including temperature, current density, type of plating bath and tank and barrel plating. Plating in which gassing occurs and most alkaline baths usually cannot be used. Flash coat of copper, nickel or silver is necessary if any of the questionable baths are to be used.—INCO. 10795

5.4 Non-Metallic Coatings and Paints

5.4.2

Distribution of Crystals in Titania

Enamels Fired Directly on Steel. E. D. LYNCH AND A. L. FRIEDBERG. Paper before Am. Ceramic Soc., 56th Ann. Mtg., Chicago, April 21, 1954. *J. Am. Ceram. Soc.*, 38, No. 8, 257-263 (1955) Aug. 1.

Technique for studying relation of crystalline nature of enamel to the bond developed on fired enamel specimens. Main difference in crystalline nature is presence of ferrous oxide crystals at interface of good bond specimens and their absence in poor bond specimens. All samples were nickel-flashed (0.066-0.129 grams per sq. ft. surface). Samples prefired at 1500F for 30 sec. and acid etched showed excellent bond. Photomicrographs show these samples to have greatest amount of nickel or nickel-iron alloy deposit between the steel and the enamel. Technique of examining sample from enamel surface toward steel is superior to that of acid etching metal and examining toward enamel which dissolves iron-nickel alloy at interface. Tables, X-ray diffraction data, photomicrographs.—INCO. 10445

5.4.2

Recent Development in the Technology of Porcelain Enamelling on Steel in the United States of America. E. M. HOMMEL. O. Hommel Co. Paper before Institute of Vitreous Enamellers. *Sheet Metals Inds.*, 32, No. 339, 531-536 (1955) July.

Article to be enamelled by Eckel-Romine process of direct white application is given an acid pickle and nickel-sulfate dip after cleaning. About 10 minutes immersion time in standard nickel-dip tank is usually sufficient. Nitric-acid pickling step and nickel-deposition step in Ferro-Republic direct application process require rigorous control. Nickel is deposited by chemical reduction rather than galvanic displacement. More continuous nickel layer is obtained by this method. Nickel deposition bath contains nickel sulfate, sodium acetate and sodium hypophosphite. Application of titania-opacified enamels direct to titanium steel, luminescent porcelain enamels and latest developments in spraying and grinding are also discussed.—INCO. 10377

5.4.2, 3.5.9

Investigation Directed Toward the Development of Ceramic Coatings with High Reflectivities and Emissivities for Use in the Aircraft Power Plants. Quarterly Report No. 3. JAMES C. HALE AND EDWARD A. DOUGLAS. Bettinger Corp., Waltham, Mass., January 15, 1955, 38 pp.

Tests were made on the oxidation resistance of various metals and the effects of oxide diffusion through emissive coatings were considered. Tests were also made to check possible emissivity changes which might occur between a durable enamel and one which had been oxidized. The emissivity data on emissive coatings are discussed. The method of recalibrating the emissivity machine was also given in detail. Data are given on the development of oxidation resistant coatings. Reflective oxide emissivities and the effect of glass on emissivity of pure oxides are also studied.—NSA. 10769

5.4.2, 4.7

Metallic Materials Resistant to Molten Zinc. W. HODGE, R. M. EVANS AND A. F. HASKINS. *J. Metals* (Trans. AIME), 7, No. 7, 824-832 (1955) July.

Refractory boron compounds resist corrosion by molten zinc. Coatings were made from ferro boron and manganese



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boron by several methods: welding, hard facing and pack diffusion; and techniques of coatings are very important. Mechanical failure of the diffusion coatings can be partially eliminated by applying them to Type 416 chromium steels rather than carbon steels. Welded coatings made with a tungsten arc are better than those made by other welding methods. Sintered compacts of mixtures of iron and chromium borides developed strengths of 30,000 psi. They resisted corrosion by zinc at 600C and oxidation at higher temperatures. Tabulation of the results of zinc corrosion tests include stainless 446 and 310, Hastelloy B and C, Stellite 21, Colmonoy No. 6, Duriron and cast iron. Strengths of sintered borides (including chromium boride-cobalt-nickel and chromium boride-nickel) are compared with those of graphite and gray iron. Microstructures of Types 416 and 430 are shown. 23 references.—INCO. 10381

5.4.2, 5.4.5

Metal Finishes—Paint Versus Porcelain. J. P. GARDNER. *Ind. Finishing (USA)*, 31, No. 4, 42-44, 46, 48, 50, 52, 54 (1955).

Economic and other factors affecting the replacement of vitreous coatings by new types of surface coating are discussed.—RPI. 10582

5.4.3, 4.6.2, 4.6.3

Rubber Lining Prevents Corrosion of Metal Piping. *Heating, Piping, Air Conditioning*, 27, No. 2, 100 (1955) Feb.

Report from Natural Rubber Bureau on a British auto maker's experiment with rubber lined pipe. Salt and other impurities in brackish boiling water drawn from boreholes caused corrosion right through walls of unlined steel pipe in only eight months. Rubber lined main, installed in 1948, is said to be in excellent condition today after six years of operation under same negative condition.—INCO. 10370

5.4.5

Paint Faults and Remedies. Part II. Peeling. H. COURTNEY BRYSON. *Corrosion Prevention and Control*, 2, 27-31, 41 (1955) June.

Requisites for obtaining good adhesion include preparation of a clean surface, immediate application of paint, use of corrosion resistant primer and a good top coat. Photograph.—BTR. 10498

5.4.5

Corrosion Protection by Cold Zinc Coating. (In German.) I. C. FRITZ. *Metall*, 9, No. 11/12, 488-489 (1955) June.

Evaluation of the protective effect and properties of zinc-dust paint and zinc-paste coatings. Photographs. 6 references.—BTR. 10522

5.4.5

Corrosion Resistant Paints. HENRY L. BEAKES. *Official Digest, Federation of Paint and Varnish Production Clubs*, 27, 366-370 (1955) June.

Properties of films; surface pretreatment; painting tips. Fourteen references.—BTR. 10518

5.4.5

Tests on the Relative Efficiency of Chromate Pigments in Anti-Corrosive Primers. H. G. COLE. *J. Applied Chem.*, 5, No. 5, 197-208 (1955) May.

Results of sea-water spray corrosion tests on rolled sheet magnesium-1.4 percent manganese, magnesium-1.7 percent manganese, aluminum-4.0 percent

copper-0.8 percent magnesium-0.7 percent manganese-0.6 percent iron and a steel (0.4 percent manganese, 0.2 percent chromium, 0.1 percent carbon) and extruded strip magnesium-6.3 percent aluminum-1 percent zinc, painted with primers made from 17 chromate pigments incorporated in an oil/coumarone medium. Strontium chromate gave best overall protection.—BNF. 10511

5.4.5

Acid and Alkali Resistant Protective Paints. Part I. Chlorinated Rubber Paints. W. L. YEO. *Corrosion Prevention & Control*, 2, No. 8, 25-27, 50 (1955) August.

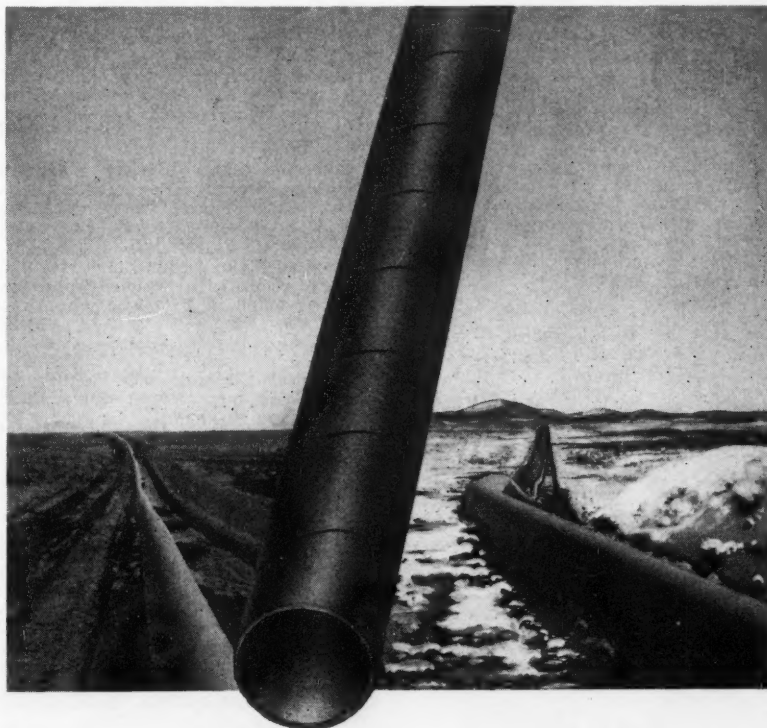
Corrosion conditions encountered in manufacturing processes using acids and alkalis are immersion, spillage, fumes and atmospheric pollution. Normal 3-coat

system of chlorinated rubber paint is effective in protecting against fumes and general atmosphere, but for more critical conditions 4-coat system with special surface preparation is used.—INCO. 10354

5.4.5

Bitumen in the Prevention and Control of Corrosion. R. P. BELL AND K. A. WHEELDON. *Corrosion Prevention & Control*, 2, Nos. 10, 11, 30-34, 33-37 (1955) October, November.

Reviews origin, crude oil refining and bitumen production, coating properties of bitumen, application, bitumen paints, bitumen emulsions with colloidal clays and soaps and properties of these emulsion films and surface preparation prior to application. 9 references.—INCO. 10690



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5.4.5, 1.6, 5.9.1

Industrial Maintenance Painting. PAUL E. WEAVER. Book, 1955, 82 pp. Published by Paul E. Weaver, 4025 Brady Street, Baton Rouge 5, Louisiana.

Based in part on his personal experience and prepared in anticipation of its use in part as a thesis toward a master's degree in mechanical engineering, the book crams a wide variety of information into small compass. Of especial interest are the tables which give unusually concise data on various aspects of industrial painting. Such subjects as paint mils film thickness per 100 sq. ft. per gallon for different solids contents; data on sandblasting equipment, such as cost of leaks due to waste of air and others are included.

The author recommends the best surface preparation, sandblasting if possible and selection of paints on the basis of a rating system which includes type of exposure. Clear illustrations of spray painting technique are included. The data on surface preparation are more extensive than on other aspects of the painting problem.

Considerable information on the economics of painting is included. The author contends, for example, that performance data on sandblasting are not always accurate because there usually is inadequate information on the efficiency of the operations. The significance of relatively minor points, frequently ignored, is emphasized. 10327

5.4.5, 2.2.5

Acid-Truck Painting Cost Cut 85%. *Chem. Eng.*, 62, No. 2, 218, 220, 222 (1955) Feb.

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5.4.5, 3.3.4

Microbes as a Cause of the Destruction of Bitumen Insulation. (In German.) Th. Temme. *Bitumen, Teere, Asphalte, Pech*, 6, No. 5, 161-164 (1955) May.

Microbic damage of corrosion-protective coatings and oxidation of hydrocarbons. Table, photographs.—BTR. 10358

5.4.5, 6.3.6

Corrosion Keys: Surface Coatings. Aluminum-Bronze Alloys. KARL BENNING, BRUCE FADER, FRANK McELROY AND I. S. LEVINSON. *Chem. Processing*, 18, 74, 76, 78 (1955) July.

Neoprene, vinyl, epoxy and Hypalon coatings compared; aluminum-bronze alloys are listed in 16 media. Graphs.—BTR. 10488

5.4.5, 7.10

Chemical Cleaning and Painting of Railroad Bridges. JOSEPH BIGOS. *Bull. Am. Railway Engineering Association*, 57, No. 523, 1-14 (1955) June-July.

Suitability of painting chemically cleaned and pretreated surfaces in comparison with surfaces cleaned by hand-chipping and wire-brushing methods. Evaluation of the performance of a number of paints and coatings. Tables, diagrams, photographs.—MR. 10492

5.4.6

Tentative Recommended Specifications and Practices for Coal Tar Coatings for Underground Use: A Report of Technical Unit Committee T-2G on Coal Tar Coatings for Underground Use. T. F. P. KELLY, Chairman. *Corrosion*, 12, No. 1, 75-76 (1956) Jan.

Recommendations are given for practices to be adopted in the underground use of coal tar coatings. Topics discussed include coating requirements, long term performance, coal tar primer, coal tar enamels and application of coal tar coatings to pipe. 10585

5.4.6, 1.6, 2.5

ASTM Standards on Paint, Varnish, Lacquer, and Related Products. Book, 1955, 848 pp. American Society for Testing Materials, Philadelphia.

A collection of all the ASTM specifications, methods of test and definitions pertaining to paint, varnish, lacquer and related products in convenient form for use of the industry.—BTR. 10706

5.4.7

Hot Spray Painting. (In English and Spanish.) R. H. WARRING. *Machinery Lloyd* (Overseas Ed.), 27, 81-83 (1955) May 21.

By using heat, the spray contains a considerably greater proportion of solids which, with proper technique, do

not sag or run; overspray is considerably reduced, with an overall saving in production time and costs. Graph, table, diagrams.—BTR. 10334

5.4.7

Solution Coating of Copper Wire. C. A. LITZLER. Paper before Wire Assoc. Ann. Conv., Chicago, November 14-17, 1955. *Wire & Wire Products*, 30, No. 10, 1198-1203, 1206-1208, 1282-1284 (1955) Oct.

Describes in processing detail some design and engineering considerations in precision application of electrical enameling solutions to copper wire in size range of No. 8-No. 30 gauge. Types of solutions are conventional low viscosity polyvinyl formal enamels, solution nylon, solution silicone, solution Teflon, solution PVC, or plastisol vinyl. Letoff stands, in-process preannealer, wire straighteners, application system, evaporating and polymerizing furnace and capstand and takeup unit are described. Diagrams.—INCO. 10849

5.4.8

Recent Developments in Antifouling Paints. A. L. ALEXANDER. *Naval Res. Lab. Org. Finishing*, 16, No. 9, 5-10, 12 (1955) Sept.

Impetus provided by war time research on antifouling systems for ships resulted in a broader understanding of mechanisms by which successful antifouling paints function. Antifouling paints are classified according to their solution rate (soluble matrix, permeable matrix, continuous contact, and exfoliating) and properties are discussed. Use of adaptable coatings with cathodic protection to combat hull corrosion as well as fouling is reviewed.—INCO. 10461

5.5 Oil and Grease Coatings

5.5.1, 5.6.3

Petroleum Base Rust Preventives. *Lubrication*, 41, No. 6, 61-72 (1955) June.

Consideration of preservation lubricants includes turbine and hydraulic oil systems, internal combustion engines, packaging, storage and shipping of grease lubricated parts, open gear lubrication, and lubrication for wire ropes and cables. Preservative coatings (non-lubricating) include oily film coatings, soft film and hard film coatings, flotation type (marine) and soluble oil types. Surface preparation and methods of application including dipping, spraying, brushing and flotation are reviewed. Photographs of test specimens.—INCO. 10453

5.5.3, 2.3.9

Radioactive Tracer Techniques Test Rust-Oleum Coating. *Marine Eng.*, 60, No. 10, 60-66 (1955) Oct.; *Iron Steel Engr.*, 32, No. 10, 134, 136 (1955) Oct.; *Ry. Age*, 139, No. 16, 40 (1955) Oct. 17.

Radioactive tracing was used to determine the penetration of a fish-oil-based protective coating through rust to bare metal, after coating had been applied directly over rusted metal surfaces. Extensive laboratory and atmospheric testing indicated that radioactive synthesis did not change performance of standard product. Tracer results show that protective coating does penetrate through rust with 15 percent of surface radioactivity being found at bare metal. Research was conducted at Battelle Memorial Institute. Graph.—INCO. 10885

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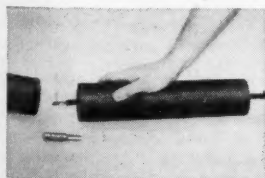
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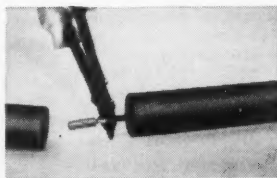
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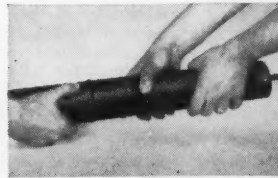
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5.9 Surface Treatment

5.9.2, 5.9.4

Patents Since 1940 on the Chemical and Electrochemical Polishing and Brightening of Metals. (In German.) H. BAUR. *Metalloberfläche*, Ser. A, 9, No. 2, 22A-28A (1955) February.

A series of concise tables giving numbers and dates of patent specifications of various countries, composition of bath, additives and temperature of operation. Tables cover chemical brightening of aluminum and alloys; magnesium; iron and steel; copper, nickel and alloys; zinc and cadmium. Electrochemical brightening of aluminum and alloys; magnesium and alloys; iron and steel; nickel, chromium and alloys; copper and alloys; zinc, cadmium and alloys; noble metals.—BNF. 10485

5.9.4, 1.6

The Phosphating of Metals. W. MACHU (E. Venturi, Translator). Book, 1955, 286 pp. U. Hoepli, Milan.

This book, an Italian translation of a German original (published by Verlag Chemie, Weinheim), itself the work of a specialist of international reputation, is a comprehensive review of the historical, scientific and technical aspects of phosphating metals. The subject is of general interest to the paint technologist and the work under review can be recommended as well-written and authoritative. Some sections deal specifically (but not in great detail) with paint technology aspects, notably, the use of wash primers and of phosphating as a paint pretreatment.—RPI. 10876

5.9.4, 5.9.2

The Electrolytic and Chemical Polishing and Brightening of Aluminium and Its Alloys. A. W. BRACE. *Metal Finishing J.*, Nos. 6, 7, 253-258, 278; 319-323 (1955) June, July.

Surveys main processes of industrial importance, with mention of laboratory methods which may become commercial in the future. Definition of brightening and polishing theory of electropolishing, chemical polishing and brightening; industrial electropolishing and electro brightening baths; chemical polishing and brightening solutions and galvanic polishing. 29 references.—BNF. 10714

5.9.4, 6.3.3

Electropolishing of Chromium and Its Alloys. K. F. LORKING. *Bull. Inst. Met. Finishing* (Trans. IMF), 5, No. 2, 119-126 (1955) Summer.

A bath containing 64 vol. percent phosphoric acid, 15 percent concentrated sulfuric acid, balance distilled water has been successfully applied to the smoothing and polishing of electrodeposited chromium, massive chromium and chromium alloys. Under certain conditions surfaces suitable for metallographic observation are obtained. Operation of the bath and nature of the polishing action are discussed in detail. The ultimate purpose of this work is to investigate the change of properties of chromium caused by polishing action: this will be described in other papers.—BNF. 10850

5.9.4, 6.3.6

The Influence of a Surface Active Agent on the Electropolishing of Copper. K. F. LORKING. *J. Electrochem. Soc.*, 102, No. 8, 479-484 (1955) August.

Various experiments indicate that cetyl

trimethyl ammonium bromide has two beneficial effects on the electropolishing of copper in phosphoric acid: 1) it is adsorbed on the anode surface and assists the normal anodic film to improve the micropolishing action 2) it is adsorbed on the surface of oxygen bubbles and accelerates their release, thus decreasing the size of the pits formed.—BNF. 10864

5.9.4, 6.3.13

Relation of Colour to Certain Characteristics of Anodic Tantalum Films. A. F. TORRISI. *J. Electrochem. Soc.*, 102, No. 4, 176-180 (1955) April.

Anodic oxidation of tantalum over a range of formation voltages and temperatures; film thickness is related to the capacitance/unit area.—BNF. 10348

5.9.4, 6.3.13

The Crystallization of Anodic Tantalum Oxide Films in the Presence of a Strong Electric Field. D. A. VERMILYEA. *J. Electrochem. Soc.*, 102, No. 5, 207-214 (1955) May.

Author had previously shown (*Acta Metallurgica*, 1, No. 3, 282-294 [1953] May) that tantalum could be anodized and that the amorphous anodic films produced could then be crystallized on heating at about 800°C. Present paper shows that temperatures of 0-100°C can be used if a strong electric field is applied across the film; process is termed field crystallization.—BNF. 10347

5.9.4, 6.4.2

Fine-Scale Structures Produced on Aluminium by Electropolishing or Etching. N. C. WELSH. *Research*, 8, No. 6, S28-S29 (1955) June.

The periodic markings, observed on electron microscope replicas of aluminium surfaces after electropolishing in a perchloric acid-alcoholic mixture, were studied by investigating the effects of anodic treatment in several other electrolytes. The different types of surface-structure produced are described and the effect of voltage on the spacing between equivalent points was established.—ALL. 10329

5.9.4, 6.4.2

Colouring of Anodically Oxidised Aluminium with Inorganic Pigments. (In German and French.) E. HERMANN AND W. HUBNER. *Aluminium Suisse*, 5, No. 4, 134-138 (1955) July; translation: Aluminium Laboratories Ltd. Report No. B-TM-172-55.

Coloring of oxide films by chemical reaction of two inorganic compounds in the pores of the oxide film, by decomposition of a compound or by impregnation of pores with a colored compound. Range of gold colors by decomposition of $(\text{NH}_4)_2\text{Fe}(\text{C}_2\text{O}_4)_2$ to $\text{Fe}(\text{OH})_3$; bronze colors by reaction of cobalt acetate with KMnO_4 , other methods also suggested; white by lead acetate in the pores (laboratory process only); also coloring of film yellow, brown, red, green, blue or black.—BNF. 10776

5.9.4, 6.4.2

Anodic Oxidation of Semi-Products Obtained from Sintered Oxidized Aluminium Powders. (In French.) J. HERGUEL, P. LELONG AND M. LE NOUAILLE. *Rev. met.*, 52, No. 5, 369-374 (1955) May.

The presence of numerous small barriers of aluminum oxide in the sinter considerably modifies conditions for anodizing, essential differences com-

pared with normal aluminum being increased resistance of the electrolytic cell and a grey or black color of the film produced; constitution of powder particles and methods of sintering also have influence.—BNF. 10770

5.9.4, 6.4.2, 2.3.6

Electron Micrographs from Thick Oxide Layers on Aluminium. C. J. L. BOOKER, J. L. WOOD AND A. WALSH. *Nature*, 176, No. 4474, 222-223 (1955) July 30.

Letter: Using the evaporated carbon film technique, electron micrographs were obtained of both the top surface and the cross-section of thick oxide layers on aluminium. An electron micrograph was obtained from the top surface of an oxide layer prepared in 5 percent chromic acid. The specimen was electropolished 99.99 percent pure aluminium strip anodized at 40°C, the voltage reaching 90 V. at the end of 100 minutes. A nitrocellulose-backed 'Formvar' replica was stripped from the surface on Scotch tape and a carbon film evaporated on to it. This was shadowed in situ with gold-palladium alloy at an angle of approximately 20 degrees, the replica then being mounted on a copper specimen grid and the plastic dissolved away with organic solvents. The shadowed carbon replica formed a 'negative' of the original surface and was examined at a magnification of 12,400. The micrograph has been enlarged to a magnification of 25,000. The section micrograph was obtained from an oxide cross-section prepared in 17.5 percent v/v sulfuric acid. The specimen was a strip of electropolished 99.99 percent pure aluminium anodized at room temperature for sixty minutes at a current density of 50 m. amp./sq. cm. The anodized strip was mounted in a moulded block with 'Araldite' casting resin D. A cross-section normal to the plane of the oxide surface was ground on fine emery papers and finally polished with magnesia on a rotating cloth. The replica was obtained as before. It was shadowed in the direction of the metal/oxide boundary and examined at a magnification of 10,000. In the micrographs a region at the metal/oxide boundary is shown with the tubular-shaped pores running up to the interface.—ALL. 10633

5.9.4, 3.8.4

A Theory of the Kinetics of Formation of Anode Films at High Fields. J. F. DEWALD. *J. Electrochem. Soc.*, 102, No. 1, 1-6 (1955) January.

A theory is presented for the anodic oxidation of metals such as tantalum and aluminium. The theory of Mott and Cabrera has been extended to include effects of space charge on kinetics of the process in the high-field case. The behavior of these systems is shown to depend critically on a dimensionless factor, δ , which is determined by the lattice and energy parameters and also by the experimental conditions. For δ very small, corresponding to small space charge, the kinetic equation reduces to that of Mott and Cabrera. For large values of δ a very similar equation results which, however, contains only the parameters of the bulk oxide. For intermediate values of δ , complex behavior is predicated. In particular, the temperature independence of Tafel slope observed for tantalum is shown to be a consequence of the theory for certain reasonable choices of the parameters.—ALL. 9985

5.9.4, 3.7.3

Change to Gas-Carburizing Improves Piston Pins. R. E. HAISLIP. Chrysler Corp. *Materials & Methods*, 41, No. 6, 140-143 (1955) June.

Surface hardening method of wrist pins used in every Chrysler Fire Power V-8 engine was changed from pack carburizing to gas carburizing to reduce process time and improve quality factors. Much shorter over-all production cycle resulted due to elimination of 2 heat-treat operations, and uniformity increased through each pin and from pin-to-pin. New surface hardening system included gas carburizing at 1680F, quenching in caustic solution, washing, and tempering at 400F for 30 min., 58 RC min. Production test results of AISI-1117 steel piston pins after gas carburizing and quenching are tabulated.—INCO. 9987

5.9.4, 5.9.2

Phosphate Finishes. N. P. GENTIEU. *Am. Chem. & Paint Co. Product Eng.*, 26, No. 4, 190-194 (1955) April.

Surface treatments, important for corrosion resistance and paint bonding, are discussed. Chemical surface treatments include cleaning without reaction with the metal surface, cleaning with surface modification and cleaning with surface conversion. Description is given of phosphate finishes, and properties are discussed.—INCO. 10010

5.9.4

Phosphating and Chromating (of Aluminum). (In German.) H. KELLER. *Aluminum*, 31, No. 1, 4-7 (1955) Jan.

Critical account particularly of acid methods (chromating and phosphating) of treatment of aluminum and alloys as a basis for painting; physical and chemical properties of films produced are tabulated; methods of operation. Unlike these methods, which produce a film in itself corrosion resistant, wash primers only provide a temporary resistance, rapid application of paint being necessary.—BNF. 10278

5.9.4, 6.4.2

Conductive Coating for Aluminum. J. A. CONNOR AND R. STRICKLEN. *Elec. Mfg.*, 55, No. 6, 105-107 (1955) June.

Contact resistance and corrosion properties of aluminum components are improved by chromate surface conversion treatment, Iridite No. 14, applied by immersion at room temperature. Surface electrical characteristics were evaluated by direct current, radio-frequency current and low-frequency alternating current tests. Tests were applied to specimens, including silver-plated, clear aluminum and Iridite-treated aluminum, before and after a 64-hour standard salt spray exposure. Surface resistance of aluminum treated with Iridite is higher than that of ideally clean aluminum but is still acceptably low for practical use. Necessity for masking of components and removal of deposited coating is eliminated. Iridite-treated aluminum does not deteriorate drastically from its original condition under salt-spray exposure. Tables, graphs, illustrations.—INCO. 9957

5.9.4, 2.3.7

Quality Control of Anodic Films. (In German.) F. BAUMANN AND R. LATTEY. *Aluminum*, 31, No. 5, 199-204 (1955) May.

Methods are proposed to control thickness, resistance to corrosion and to mechanical abrasion, porosity and electrical

how to CUT CORROSION LOSSES

a report by Koppers Company, Inc.



C. U. Pittman
Supervisor Technical Service

Ideally, effective corrosion control should start in the design stage of a new building or unit. The design engineer—by avoiding sharp edges, grooves, thin supporting members, etc.—can eliminate many of the common starting points for corrosion.

But in any case, the first step in preventing corrosion is *adequate preparation of the surface* before applying the protective coating. A really good—and economical—protective coating should *prevent* corrosion, not just cover corrosion products.

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Most authorities agree that there are two chief objectives in good surface preparation: removing contaminating materials and producing a surface that will promote a good mechanical bond with the coating. The life and effectiveness of the coating system depends upon the degree to which you attain either of these objectives.

Actually, a tightly adherent surface of mill scale would make an ideal protective coating in itself—if temperatures remained constant. But since the scale and the virgin metal have different co-efficients of expansion, temperature changes and mechanical flexing cause flaking of the mill scale even under coatings. (Note: In over-the-ditch coating, it is not practical to remove all mill scale—buried pipe is not so subject to temperature change.) Another problem with mill scale is that electrochemical action between the mill scale and the metal accelerates corrosion and causes pitting.

Rust provides a certain amount of protection by slowing corrosion. But since it is non-adherent and porous, corrosion continues.

To perform an effective, long-life job, any coating must have a proper surface to which it can adhere. As revealed by photomicrographs, a slight roughness produces the best mechanical bond by increasing surface area and providing a tooth for the coating. Chemical bonding depends on the inherent molecular structure of the coating material. Some coatings must depend on a mechanical bond only. But coal tar coatings, having polar groups, will bond chemically as well as mechanically.

* * *

The important point on which most corrosion engineers agree—and which our applications research has proved—is that surface preparation is an integral part of the coating specification. By paying as careful attention to surface preparation methods as to selecting the right coatings, you will assure trouble-free, economical corrosion control.

* * *

We will report to you soon on the various surface preparation methods. In the meantime, we'd like to hear about your corrosion problems. Write: Koppers Company, Inc., 1301 Koppers Building, Dept. 100H, Pittsburgh 19, Pa. District Offices: Boston, Chicago, Los Angeles, New York, Pittsburgh and Woodward, Ala. In Canada: Koppers Products, Ltd., Toronto, Ontario and Edmonton, Alberta.



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COATINGS AND ENAMELS

properties of anodic oxide films. The thickness of a coating can be determined by the optical microscope on polished transverse sections, with a graticule fitted in the eyepiece, or using the "difference" method, that is by measuring the position-difference of the instrument when the top or the bottom of the film is in focus, also by simply detaching the oxide film, or by means of the isometer which generates eddy-currents in the sample and by measuring their inductive effect determines the distance between search coil and sample. This latter method is said to have an accuracy of $\pm 0.5\mu$. Testing of resistance to corrosion by artificial industrial atmospheres and by treatment in a solution of 2.5 percent sodium chloride, 1.5 percent acetic acid and 0.1 percent hydrogen peroxide (weight) is described. Abrasion resistance can conveniently be determined with the instrument developed in the Siemens &

Halske Laboratories by researchers Mauksch and Budiloff or by Arlt's abrasion test. There is a simple dye-test for assessment of porosity, very suitable for industrial use. Electrical testing of the coating involves determination of the breakdown voltage or measuring of the ohmic resistance with Ruff's resistometer. Results of tests performed are given and it is concluded that isometer and resistometer tests can yield a very good assessment of the quality of anodized layers.—ALL. 9974

5.9.4, 3.7.3

Phosphate Coating Retention During Cold Extrusion of Artillery Shells. LLOYD O. GILBERT, STANLEY L. EISLER, JODIE DOSS, AND W. DENNIS MCHENRY. *Metal Finishing*, 53, 56-58, 61 (1955) April.

Use of coatings containing radiophosphorous. Approximately 8 percent of the

coating remained after extrusion. Photographs, tables, 8 references.—BTR. 9949

5.9.4

Phosphate Coating of Metal Surfaces for Industrial Use. W. R. CAVANAGH AND R. C. GIBSON. *Plating*, 42, No. 6, 742-748 (1955) June.

Factors involved in phosphate coating of steel, factors which influence crystal growth, phosphate coatings for corrosion resistance, phosphate coatings as a base for paint, phosphate coatings used as an aid in the cold forming of metals, use of phosphate coatings to reduce wear and primer treatment coating are discussed. Table shows loss in weight of manganese and zinc phosphate coatings and untreated steel due to corrosion during 16 months' exposure to rural atmosphere expressed in mgs./100 sq. cm. of surface. Illustrations and 17 references.—INCO. 9953

5.9.4, 6.4.2

Some Problems in the Brightening of Aluminium and Its Alloys. (In German.) F. BAUMANN. *Erzmetall*, 8, No. 1, 14-18 (1955) January.

After pointing to our ignorance of the nature of anodic and chemical polishing, author suggests how absence of etching attack in the polishing solution may arise from increase in removal of metal owing to partial passivation of the surface or to diffusion. He discusses also the effects of ionic concentration of the bath and of the composition of the alloy.—BNF. 9917

5.9.4, 6.4.4, 3.5.8

The effect of an Anodic (HAE) Coating on the Fatigue Strength of Magnesium Alloy Specimens. J. A. BENNETT. Paper before Am. Soc. Testing Materials, 58th Ann. Mtg., June 26-July 1, 1955. ASTM Preprint No. 77, 1955, 5 pp.

Nonmetallic coating produced electrolytically on magnesium alloys by the HAE process provides increased resistance to corrosion. To determine the effect of the coating on fatigue strength, bending fatigue tests of coated and uncoated specimens were made in machines of the constant-amplitude-of-deflection type. Coating usually provided sufficient protection so that the fatigue strength was not reduced by salt spray exposure. There was no significant difference in the effect of the coating between smooth and notched specimens. Table and graph.—INCO. 9923

5.9.4, 3.8.3

Study of the Process of Electropolishing Metals. (In Russian.) P. V. SHCHIGOLEV AND N. D. TOMASHOV. *Doklady Akad. Nauk SSSR*, 100, No. 2, 327-330 (1955) January 11.

The electropolishing of copper in phosphoric acid, nickel in sulfuric acid, zinc in sodium hydroxide, stainless steel in sulfuric acid/phosphoric acid/chromium trioxide and aluminum in sulfuric acid/phosphoric acid/chromium trioxide and sodium carbonate/sodium phosphate were studied by taking the anodic polarization curves. The theoretical treatment is based on passivation of the metal.—BNF. 9841

5.9.4, 6.4.2

Protection of Light Alloys Against Corrosion by Anodic Oxidation. (In French.) R. SEGOND. *Corrosion et Anti-Corrosion*, 3, No. 1, 45-51 (1955) January-February.

Survey of production and properties of anodic films on aluminum and its alloys; defects and preparation of metal

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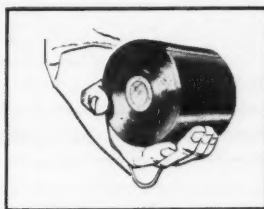


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surface. Aluminum alloys containing up to 8 percent magnesium, or 4-6 percent zinc with 1-3 percent magnesium, give thick effective films, but alloys containing more than 5 percent copper cannot be treated; applications in industry. 11 references.—BNF. 9844

5.9.4, 6.4.2

A New Process for Improving the Light Fastness of Organic Dyes on Anodized Aluminium. (In German.) C. T. SPEISER. *Aluminium*, 31, No. 1, 8-9 (1955) January.

The new method of sealing a dyed anodized aluminum consists in an after-treatment of lead, copper, zinc or chromium salts in place of the usual water or nickel cobalt acetate treatment. Sealing with these metal salts produces a substantially higher light fastness for many aluminum dyes than can be obtained by sealing with water or with hot solutions of nickel cobalt acetate. The salts used are lead acetate, copper sulfate, zinc chloride and chromium sulfate. The solutions contain 2.5 to 5 g/l and dyed aluminum is treated for 30 minutes in the boiling solution, then rinsed and dried. After prolonged use, lead acetate solution may become turbid, but the turbidity may be overcome by addition of acetic or formic acid. The table compares the light fastness of various colors sealed with water or nickel cobalt, lead acetate, copper sulfate and chromium sulfate. The numbers 4 to 5 are average light fastness, 6 to 7 are very good and 8 is excellent.—ALL. 9809

5.9.4

Some Aspects of Sulphuric Acid Anodizing to Specification D.T.D. 910C. V. F. HENLEY. Paper before Inst. Met. Finishing, London, January 17, 1955. *Bull. Inst. Met. Finishing* (Trans. IMF), 5, No. 1, 65-70 (1955) April.

Workshop difficulties in operating sulfuric acid anodizing processes to specification D.T.D. 910C are discussed. Factors influencing the choice of concentration of the electrolyte; importance of agitating the electrolyte; "spotting out" of dyed coatings caused by galvanic action; dimensional changes of aluminum basis metal occurring during anodizing; and a proposed method for maintaining the original dimensions are considered.—INCO. 10055

5.9.4, 5.3.2, 6.2.1

Corrosion- and Heat-Resistance of Carbon and Special Steels After Chemical Surface Treatment (Progress Report). W. KOHLER. *Werkstoffe u. Korrosion*, 6, No. 5, 228-236 (1955) May.

Critical review on the latest Russian literature. The formation and structure of surface layers, and the corrosion- and heat-resistance of carbon and special steels including nickel after cementation, nitriding, cyaniding, aluminizing, chromizing, silicizing, sherardizing, tungstenizing, vanadizing and treatment with beryllium and molybdenum are discussed in detail.—INCO. 10068

5.11 Design—Influence on Corrosion

5.11

Design Against Corrosion. C. F. TRIGG. *Corrosion Technology*, 2, No. 3, 93-94 (1955) March.

Methods which may be adopted in designing against corrosion include care-

ful selection of metal or material most suited to environment and service condition and use of protective treatments of zinc, aluminum, nickel, tin, phosphate and others; selection of working stresses; provision of adequate drainage; insulation of contacting surfaces of dissimilar metals to prevent bimetallic corrosion; and provision of temporary treatment for storage or transit. 7 references.—INCO. 9848

6. MATERIALS OF CONSTRUCTION

6.1 General

6.2.2

Spheroidal Graphite Iron As Material of Construction for Castings Required to Have High Mechanical Strength, Thermal Stability and Corrosion-Resistance (MTC Castings). H. TIMMERREIL. *Giesserei*, 42, 7-15 (1955) January 6.

Deals in the main with results of new experiments on spheroidal graphite iron containing 6.44 percent silicon. Summary of state of development, with special reference to damping capacity, surface hardness and successful application of spheroidal graphite iron in crankshafts and gears. Hardness tests and influence of hardening temperature (780-990°C) and structure on surface hardness and through-hardening: compositions and mechanical properties of ferritic and pearlitic test pieces. Spheroidal graphite iron regarded as ideal material for flame-hardening: Especially good results with pearlitic materials. Absence of cracks in surface-hardened spheroidal graphite iron emphasized: enhanced wear-resistance. Data on effects of silicon content on scaling behavior in 700-1000°C region: optimum silicon content found to be 6.44 percent: behavior favorably compared with that of cast iron containing 27-30 percent chromium and price advantage stressed. Comparative data for grey and spheroidal graphite irons treated at 700-1000°C. Tensile strength, Brinell hardness and combined carbon as affected by silicon content; effects of wall thickness, silicon content and heat-treatment on Brinell hardness and structural stability. Effects of temperature of heat-treatment on strength and elongation. Good machinability noted. Examples of applications of the 6 percent silicon spheroidal graphite iron in Italy.—INCO. 9976

6.2 Ferrous Metals and Alloys

6.2.2

Surface Tension of Cerium-Treated Cast Iron. R. GAUTSCHI AND B. MARINCEK. *Giesserei*, 42, 121-123 (1955) March 17.

Account of experiments at Technische Hochschule Zurich. Data on production of cast iron with spheroidal graphite structure by means of cerium additions are given. Surface tension was measured by capillary depression method, before and after cerium treatment. In all cases, surface tension was increased by certain treatment (up to 50 percent) and spheroidal graphite was formed. Sulfur contents were lowered. Notes on testing technique and on the sensitivity of the method are included.—INCO. 10006

6.2.4, 3.5.8

Mechanical-Metallurgical Improve-

ments in Drill Steel. T. W. WLODEK. Paper before Can. Inst. Mining & Met., Ann. Gen. Mtg., Montreal, April, 1954. *Trans. Can. Inst. Mining & Met.*, 58, 52-58 (1955); *Can. Mining Met. Bull.*, No. 514, 84-90 (1955) February.

Review of possibilities of metallurgical and mechanical improvements in the drill set, with particular attention to drill steel and attachments. New type of durable "spiral-rolled" drill set is introduced and its performance discussed. Typical chemical compositions of drill steels are discussed and their mechanical properties are tabulated. Steels include 3.0 nickel-0.40 chromium-0.25 percent molybdenum steel and 1.0 chromium-0.25 percent molybdenum steel. Corrosion fatigue and fretting corrosion in conical attachments are discussed. Diagrams, graphs, tables and 10 references.—INCO. 9808

6.2.4

Acceleration of the Austenite-Pearlite Transformation in a Case-Hardening Steel Containing 2% Chromium and 2% Nickel by Means of an Addition of Vanadium. S. AMMARELLER AND P. OPEL. *Stahl und Eisen*, 75, 65-69; disc., 69 (1955) January 27.

TTT diagrams for isothermal transformations, together with hardening and re-heating diagrams. Experiments were made with vanadium additions in the region of 0.1 percent. Case-hardening and "blank" hardening tests are discussed. Results showed that properties of the modified steel were similar to those of the standard material, except that in pearlitic condition, it transforms much more rapidly, thus avoiding tendency to cracking in case-hardened zone, which is a characteristic of the unmodified steel.—INCO. 9926

6.2.5

The Properties of a High-Manganese Austenitic Stainless Steel. G. N. FLINT AND L. H. TOFT. *Metallurgia*, 51, No. 305, 125-129 (1955) March.

It is shown that although in some media the corrosion-resisting properties of a stainless steel containing 18 percent chromium, 10 percent manganese, 2 percent nickel, stabilized with titanium are equal to those of a titanium-stabilized 18-8 chromium-nickel steel, there are many industrial applications for which the high-manganese steel would not be suitable. The ductility and deep-drawing properties of the high-manganese steel are inferior to those of the 18-8-titanium type. (auth).—NSA. 10015

6.2.5, 6.2.4

Recent Progress in Alloy and Special Steels. G. T. HARRIS AND E. JOHNSON. *Metallurgia*, 51, No. 303, 17-23 (1955) January.

Interesting developments in the field of constructional steels, tool steels, and corrosion- and heat-resisting steels are summarized. Composition is given of a low alloy steel containing 0.15 carbon, 0.78 manganese, 0.73 nickel, 0.92 chromium, and 0.14 percent vanadium. New hot work tool steels are reported and contain 10 percent tungsten, 5 percent chromium-molybdenum-tungsten, 5 percent chromium-molybdenum-vanadium, and 6 percent tungsten-nickel-chromium. Substitute stainless steels containing 17 percent chromium are well known. Alloys containing 18 percent chromium with 6-14 percent manganese can be rendered austenitic by addition of 0.1-0.15 percent nitrogen and 2-6 percent nickel. One grade in U. S. contains

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15 chromium, 16.5 manganese, 1 nickel, 0.15 nitrogen and 0.1 percent carbon, with properties similar to 18-8 in most respects. Americans are using increasing quantities of 25 nickel, 14 percent chromium, titanium-hardened steels (Discalloy A.286) developed from the war-time German Tinidue. Review also is concerned with heat treatment of steels. Tables.—INCO. 10283

62.5

Transformation and Segregation Phenomena in Austenitic Chromium-Nickel Steels at Elevated Temperatures. E. BAERLECKEN AND W. HIRSCH. *Stahl und Eisen*, 75, No. 9, 570-579 (1955) May 5.

Investigations of steels containing 0.055-0.29 carbon, 0.21-3.2 silicon, 0.25-3.0 manganese, 0.035 aluminum, 15.4-20.8 chromium, 0-2.9 molybdenum, 7.7-15.8 nickel, 0-0.22 nitrogen, 0-2.0 niobium, 0-1.9 titanium and 0-1.25 percent vanadium on the effect of carbon, silicon, manganese, molybdenum, niobium, nitrogen, titanium and vanadium contents on the structure, magnetic saturation, notch toughness, hardness and resistance to grain disintegration in a boiling copper sulfate-sulfuric acid solution after an annealing treatment of up to 18,500 hours at 600-850°C. 34 references and illustrations.—INCO. 9924

62.5

Stainless Steel Powder Parts. A. ADLER. *Materials & Methods*, 41, No. 3, 118-120 (1955) March.

Prealloyed powders made by chemical method have good wear and strength properties and high corrosion resistance. Production of stainless steel porous filters through gravity sintering and by conventional methods is considered. Physical and mechanical properties obtainable for structural parts depend on various combinations of compacting pressures, sintering temperatures and times and coining pressures. Typical properties of compacts sintered in dry hydrogen and properties of prealloyed 302 and 316 stainless powders are tabulated. Uses include gaskets, gears and cams. Teflon powders have been mixed with stainless powders to increase wear, strength and abrasion properties of sintered Teflon. Design and cost factors are discussed. Illustrations.—INCO. 9925

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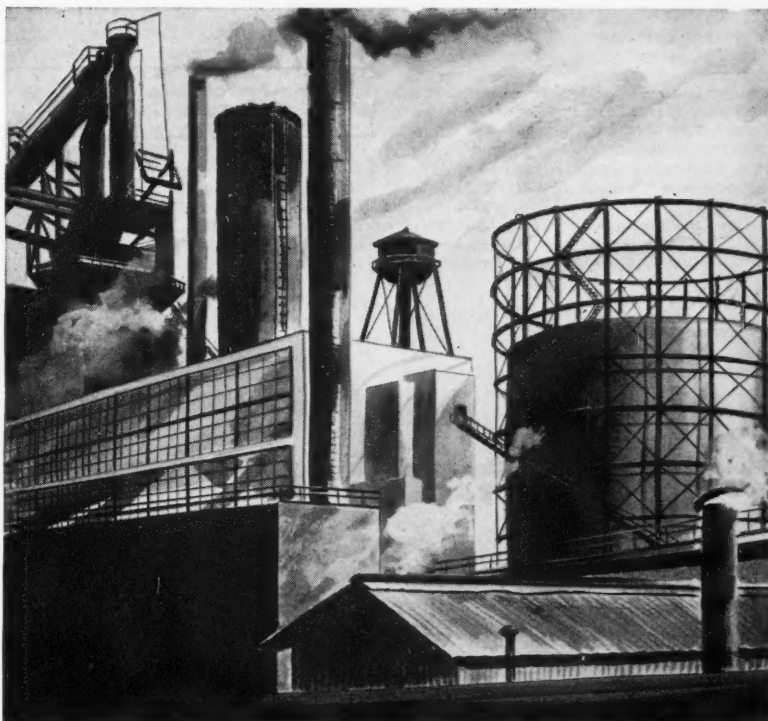
New Stainless Steels Containing 17% Chromium-4% Nickel-6% Manganese and 18% Chromium-5% Nickel-8% Manganese. Am. Iron Steel Inst. Contribution to the Metallurgy of Steel, No. 47, May, 1955, 10 pp.

New stainless steels containing 17 percent chromium-4 percent nickel-6 percent manganese (Type 201) and 18 percent chromium-5 percent nickel-8 percent manganese (Type 202) are discussed. Composition, physical and mechanical properties, including tensile, impact and elevated temperature properties, corrosion resistance to some acids and welding are covered. Properties of 17-4-6 composition are more completely described than those of 18-5-8. Graph and tables.—INCO. 9928

62.5, 3.7.2, 3.7.3

Effect of Various Alloying Elements on the Properties of Austenitic Chromium-Nickel Steels Showing High Strength at Elevated Temperatures in the Temperature Range of from 600 to 700°C. H. A. VOGELS. *Stahl und Eisen*, 75, No. 9, 559-570 (1955) May 5.

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loys such as a steel containing niobium, 16 percent chromium, 13 percent nickel, up to 20 percent cobalt with and without additional carbide forming elements as well as additions of molybdenum, vanadium and nitrogen, regarding the effect of the pre-treatment on the hot shaping property, creep strength depending on time, tendency to embrittlement and resistance to scaling at 600-700°C. Weldability and causes of the susceptibility to hot and micro-cracks of stable austenitic weld joints are discussed. Tables, photomicrographs and 17 references.—INCO, 9863

6.2.5 Cast Stainless Steel. E. A. SCHOEFER. *Machine Design*, 27, No. 5, 203-205 (1955) May.

Machining and welding procedures of corrosion-resistant and heat-resistant grades of cast stainless alloys are given. Compositions of corrosion-resistant grades, designated as CA, CB, CC, CE, CF, CH, CK and CN, and heat-resistant grades, designated as HA, HC, HD, HE, HF, HH, HI, HK, HL, HN, HT, HU, HW and HX are tabulated.—INCO. 9828

6.2.5.7.1

A Turbine-Blade Alloy Castable and Low in Cobalt and Columbium (Niobium). W. SIEGFRIED AND F. EISERMANN. *Metal Progress*, 67, No. 1, 141-146 (1955) January.

The experimental evolution of an alloy of iron with 18 chromium, 17 nickel, 4 manganese, 4 cobalt, 1 niobium, 2 tungsten, 3 molybdenum, 0.1 carbon, 0.2 percent nitrogen for mass production by investment casting. Creep and stress rupture tests (the latter in comparison with Nimonic 80 and G18B). Addition of manganese is said to permit of halving the cobalt and cadmium in G18B without loss of hot strength at 750°C. Work described is claimed to show that cast turbine blades are no more susceptible to thermal shock than forged blades.—BNF. 9801

6.2.5

Wrought Stainless Steel. B. T. LANPHER. *Carpenter Steel Co. Machine Design*, 27, No. 5, 183-190 (1955) May.

Standard types of stainless steels, austenitic, ferritic and martensitic are reviewed with a discussion of their properties and fabrication characteristics. Machinability, hot and cold working, forging, cutting and shearing, stamping, deep drawing, welding, brazing, soldering and finishing of AISI stainless steels are considered. Tables.—INCO. 10072

6.2.5, 6.3.10

Heat Resistant Cast High Alloys. C. K. LOCKWOOD. *Alloy Casting Inst. Product Eng.*, 26, No. 2, 163-167 (1955) Feb.

Data on creep strength, rupture strength and corrosion resistance under repeated heating cycles in atmospheres above 1200°F for three classes of cast high alloys. Iron-chromium alloy castings containing 18-30 percent chromium and designated by HB, HC and HD types are used for resistance to oxidation. Iron-chromium-nickel alloy castings containing 18-32 percent chromium, 8-22 percent nickel and designated by HE, HF, HH, HK and HL types are used in sulfur, oxidizing and reducing atmospheres. Iron-nickel-chromium alloy castings containing 68 percent nickel, 10-21 percent chromium and designated by HT, HU, HW and HX types are used in chemically reactive media and under conditions involving thermal shock. See also Strength of Cast Alloys at 1200°F, by J. R. Lane

(*ibid.*, 25, No. 6, 207, 209, 211 (1954) June. 10075

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.4, 3.7.2

Influence of Boron on Cast Cobalt-Base S-816 Alloy. W. E. BLATZ, E. E. REYNOLDS AND W. W. DYRKACZ. *Am. Soc. Testing Materials Preprint No. 94a*, 1955, 8 pp.

Cast cobalt-base alloys with stress-rupture properties at 1650°F equivalent to those of S-816 alloy at 1500°F were developed in the investigation described. This outstanding strengthening effect resulted from additions of boron, the influence of which was studied extensively. Optimum rupture strengths plus good rupture ductility are obtained with 1 percent boron. Alloys also possess excellent casting characteristics. Base alloy used contained 0.4 percent carbon, 1.2 percent manganese, 0.4 percent silicon, 20 percent chromium, 20 percent nickel, 4 percent molybdenum, 4 percent tungsten, niobium+tantalum, 2 percent iron, balance cobalt. Graphs, tables, and photomicrographs.—INCO. 9972

6.3.6

The Influence of Impurities on the Properties of Sand-Cast Bronzes. (In French.) P. J. LE THOMAS. *Fonderie*, No. 109, 4392-4396 (1955) February.

A survey of effects of iron, nickel, manganese, aluminum, sulfur, phosphorus, antimony, arsenic and silicon on the properties of tin bronzes: mechanical properties; oxidation and chemical reactions of impurities; modification of distribution or of properties of α - or δ -phases. 29 references.—BNF. 10084

6.3.6, 2.2.2

The Atmospheric Corrosion of Copper: Results of 20-Year Tests. D. H. THOMPSON, A. W. TRACY AND J. R. FREEMAN, JR. *Am. Soc. Testing Materials*, Preprint No. 91c, 1955, 11 pp.

Eleven brands of copper, in form of sheet and wire, were exposed to four outdoor atmospheres in Connecticut. Three sets of specimens were located in natural environments (marine, rural, and normal industrial atmospheres) while a fourth set was located in an accelerated industrial atmosphere. Effect of corrosion was evaluated by loss in weight, loss in strength and gain in electrical resistance. Mean corrosion rate was found to be on the order of 50×10^{-6} in./yr. While differences were of no practical significance, purest copper corroded least and arsenical copper corroded most. Tables.—INCO. 9865

6.3.6

Copper and Copper Alloys: A Survey of Technical Progress During 1954. E. VOCE. *Metallurgia*, 51, No. 303, 9-16 (1955) Jan.

A survey under the headings: production (including utilization of scrap), foundry practice, fabrication, finishing and plating, properties and applications, corrosion, joining and physical metallurgy. 167 references.—BNF. 9878

6.3.6

Relation Between the Structure and the Tensile Properties of Sand-Cast Tin Bronzes. (In French.) P. J. LE THOMAS. *Fonderie*, No. 108, 4320-4329 (1955) Jan.

Relation established between tensile properties and distribution of (α plus β)

eutectoid phase (estimation of phase quantity from dilatometric measurements); properties affected by increasing quantities of phosphorus, with a transition zone at 0.11 percent phosphorus.—BNF. 9866

6.3.6

Wrought Non-Leaded Brasses. Materials & Methods Manual No. 12. J. L. EVERHART. *Materials & Methods*, 41, No. 1, 111-126 (1955) January.

A comprehensive discussion of a group comprising gilding metal 95/5, commercial bronze 90/10, red brass 85/15, low brass 80/20, cartridge brass 70/30, yellow brass 65/35 and Muntz metal 60/40. Tables of physical and mechanical properties. Sections on engineering properties (including corrosion resistance), processing characteristics (forming and fabricating), heat treatment, machinability, joining, surface finishing; applications.—BNF. 9994

6.3.6

Dispersion Hardening of Copper-Chromium Alloys. W. R. HUBBARD, JR. AND W. E. HART. *J. Metals* (Trans. AIME), 7, No. 1, Section 2, 200-202 (1955) Jan.

In order to throw light on the explanation of dispersion hardening by dislocation theory, room temperature flow characteristics of copper-chromium alloys (up to 1.15 percent chromium) were determined from true stress/true plastic strain curves and found to be related to the amount and characteristics of the chromium-rich precipitate.—BNF. 10040

6.3.6

The Control of Quality in the Heat-Treatment and Finishing of Copper and Copper-Base Alloys. V. B. HYSEL AND T. W. COLLIER. *J. Inst. Metals*, 83, No. 6, 233-246 (1955) February.

Heat-treatment of copper and copper-base alloys including precipitation-hardening type (copper-chromium, copper-beryllium, copper-nickel-silicon); complex aluminum-bronzes; removal of internal stress; final shaping process (shearing of sheet, slitting of strip, manufacture of circles, straightening of wire and rod; straightening, cutting to length, deburring of drawn bars and sections and tubes); inspection (including composition, surface quality and internal defects, dimensions and tolerances; mechanical, electrical, hydraulic, mercurous nitrate and grain-size tests, etc.); packaging and dispatch.—BNF. 10043

6.3.8, 3.7.4

A Note on the Influence of Grain Boundary Flow in the Creep of a Lead-0.5% Tin Alloy. P. BROCK. *J. Inst. Metals*, 83, No. 5, 191 (1955) January.

Effect of grain size on creep rate and of stress and grain size on grain boundary sliding have been demonstrated on similar specimens of a lead-0.5 percent tin alloy. Work done by the Brit. Non-Ferrous Metals Res. Assoc.; reprints are available as R.R.A. 1057P.—BNF. 9944

6.3.10, 6.3.4, 5.3.2

Super Alloys Climb into Overalls. F. S. BOERCKE. *Western Industry*, 20, No. 3, 58, 60, 62, 64-65 (1955) March.

Use of cobalt and nickel base superalloys in field of industrial maintenance is discussed. Specific applications include: Hastelloy C for hard-facing die pots, vibrating conveyor chute encountering temperatures up to 1600°F, paddles in pickling installation, roasting and leaching equipment of a uranium refining mill and electrode in an electrostatic

precipitator; Hastelloy B for coating seats on gates of hydroformer flue gas line valves in petroleum refinery; Haynes 90 for hard-facing inside of pipes carrying carbon-covered catalyst in cracking unit of oil refinery; and Multimet for heat-treating cans used in pack carburizing and annealing metal parts. Aircraft applications, such as Stellite turbine blades and Hastelloy B turbine wheels for the Boeing 502 gas turbine engine are also considered.—INCO. 9943

6.3.10, 6.3.4

The Effect of Cobalt on the High Temperature Oxidation of Nickel. S. F. FREDERICK and I. CORNET. *J. Electrochem. Soc.*, **102**, No. 6, 285-291 (1955) June.

Nickel-cobalt alloys, prepared from high purity carbonyl nickel and pure cobalt sponge, were oxidized in air at 800-1400°C. Assuming that nickel-cobalt alloys oxidize according to the parabolic rate law, oxidation rate increased with increasing cobalt content, but effect was small until over 11 percent cobalt was added. Above 60 percent cobalt, rate increased rapidly. Absolute value of oxidation rate of pure nickel was found to be below previously reported values. Activation energy of oxidation for pure nickel of 51 kcal/mole decreased with increasing cobalt to about 28.8 kcal/mole for pure cobalt. Graphs, photomicrographs, 14 references.—INCO. 10004

6.3.11

The Platinum Group Metals. E. M. WISE. Paper before Platinum Metals Symposium, Soc. Francaise de Metallurgie, Journees d'Automne, October, 1954. *Rev. met.*, **52**, 265-286 (1955) April.

Covers world production of platinum metals, applications, physical properties of pure platinum, lead, iridium, ruthenium, osmium, rhodium, purity of platinum, palladium-ruthenium, platinum-iridium, platinum-ruthenium, platinum-rhodium, platinum-tungsten, platinum-gold, platinum-nickel, platinum-cobalt, platinum-copper, palladium-silver, palladium-nickel, palladium-copper and palladium-aluminum alloys.—INCO. 9906

6.3.14, 5.3.2, 1.7.1

Annual Report, 1954. International Tin Research Council. Pamphlet, 1955, 28 pp. Tin Research Institute, Fraser Rd., Greenford, Middlesex.

Includes short notes on research in progress: aluminum-tin bearing alloys; semi-continuous casting of bronze; copper-manganese-tin alloys; pewter (effect of silver on recovery from work softening); fatigue properties of pure tin; tin-plate and hot tinning; tin-zinc and silicon-nickel alloy plating; corrosion, etc.—BNF. 10042

6.3.15

Titanium Symposium. Papers before Am. Inst. Mining Metallurgical Engrs., Inst. Metals Div., Chicago, November 1-3, 1954. *J. Metals* (Trans. AIME), **7**, No. 2, Section 1, 234-252 (1955) Feb.

Papers include: Panel Discussion, F. H. Vandenberg (Mallory-Sharon Titanium Corp.), L. A. Best (Douglas Aircraft Co.), J. B. Sutton (duPont), R. J. Kotfila (U. S. Air Force), L. R. Frazier (Gen. Elec. Co.) and T. W. Lippert (Titanium Metals Corp. of Am.), Hydrogen Affects Critical Properties in Commercial Titanium, H. D. Kessler, R. G. Sherman and J. F. Sullivan; General Physical Metallurgy of Titanium Reviewed, E. I. Jaffee.—INCO. 10284

6.3.15

Hydrogen Affects Critical Properties in Commercial Titanium. H. D. KESSLER, R. G. SHERMAN and J. F. SULLIVAN. *J. Metals* (Trans. AIME), **7**, No. 2, Sec. 1, 242-246 (1955) Feb.

Sources of hydrogen, phase relationships, removal; effect on notch toughness, strain rate and β stabilizers. Detailed results of various tests on titanium 140A (2 percent each of chromium, iron and molybdenum) and titanium 150A (2.7 percent chromium; 1.5 percent iron) including reference to forging practice.—BNF. 10298

6.3.15

Heat-Treatment and Mechanical Properties of Titanium-Copper Alloys. F. G. HOLDEN and others. *J. Metals* (Trans.

AIME), **7**, No. 1, Section 2, 117-125 (1955) January.

Hypoeutectoid titanium-copper alloys (those studied were up to 6.83 percent copper) are responsive to heat treatment and considerable variation in mechanical properties is obtainable by transformation of the β -phase. Transformation products are similar to those of carbon-steel.—BNF. 10034

6.3.19

The Atmospheric Corrosion of Rolled Zinc. E. A. ANDERSON. Am. Soc. Testing Materials Preprint No. 91a, 1955, 9 pp.

Corrosion of zinc in the atmosphere is controlled by frequency of rain and dew-fall, acidity of the moisture and rate of drying. Corrosion rate is a maximum

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in industrial locations which combine acidic atmospheric contamination with prevalence of heavy mists and dew. Composition of zinc has only a minor bearing on the corrosion rate. Corollary data are presented which explain the findings in exposure tests conducted by Subcommittee VI on Atmospheric Cor-

rosion of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys. Tables and five references.—INCO. 9914

6.3.20, 3.5.9, 1.6

High Temperature Scaling Behavior of Zirconium. First Technical Progress Report (Covering Period April 1, 1953

to March 1, 1955). D. J. GARIBOTTI, H. M. GREEN AND W. M. BALDWIN, JR. Case Institute of Technology. U. S. Atomic Energy Commission Pubn., AECU-3013, March 15, 1955, 83 pp.

The scaling behavior of arc-melted iodide zirconium sheet in air, oxygen, nitrogen and mixtures of oxygen and



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| T-1A | Survey of Corrosion Control in California Pumping Wells. A Report of T-1A on Corrosion in Oil and Gas Well Equipment, Los Angeles Area. Pub. 54-7. Per copy, \$5.00. | TP-2 | First Interim Report on Galvanic Anode Tests. (Pub. 50-2) NACE members, \$3; Non-members, \$5 per copy. | T-5B | High Temperature Corrosion Data—A compilation by NACE Technical Unit Committee T-5B on High Temperature Corrosion. Publication 55-6. Per Copy \$5.00. |
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| | | T-5A | A Bibliography of Corrosion by Chlorine. A Report of Technical Unit Committee T-5A on Corrosion in the Chemical Manufacturing Industry, Compiled by Task Group T-5A-4 on Chlorine. Publication No. 56-2. Per Copy \$1.50. | | |

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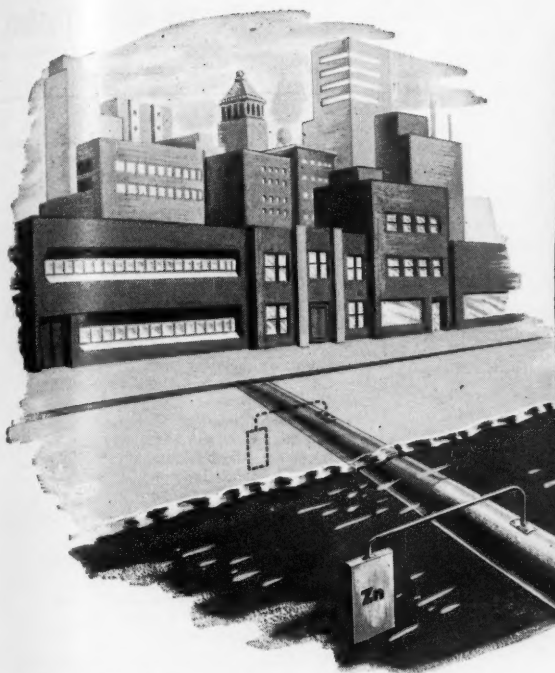
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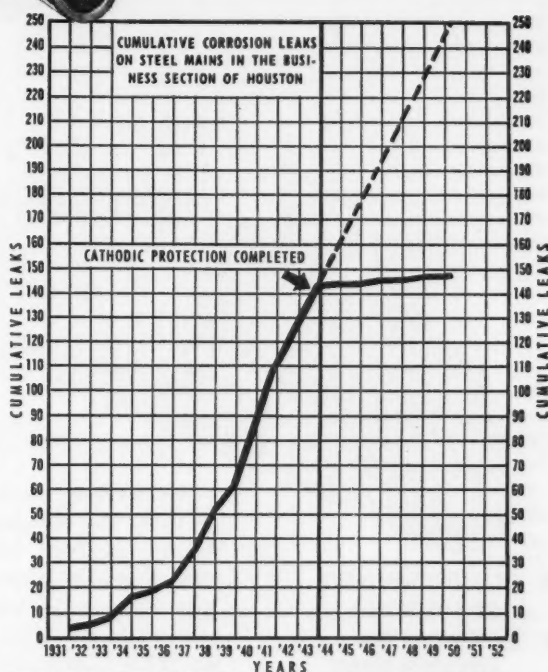
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NEARLY 50% of all the zinc consumed annually in the United States — around 400,000 tons — is used in galvanizing, i.e., protective zinc coating on iron or steel. This is ample evidence of the metal's firmly established position as industry's most effective and economical "sacrificial" weapon in its unceasing combat with rust. The electrochemical reaction between iron and zinc in galvanizing is precisely the same as that which takes place in the relatively new and growing use of zinc for cathodic protection of pipe lines and other underground iron and steel structures. The sole difference between the two methods being that in cathodic protection the zinc, in the form of anodes, is buried adjacent to a pipe line and connected by a conductor, while in galvanizing the zinc is bonded to iron or steel. In either form, zinc "protects"—as has been attested to by those progressive companies who have used zinc anodes for this purpose. For example in the northwest, a utility company reports:

"The most interesting installation was made in 1942 on four inch bare pipe located in the seepage from an irrigation ditch that circled the brow of a hill in such a manner that the pipeline trench intersecting the irrigation ditch was kept moist throughout the season. Approximately seven hundred feet of this four inch line had been replaced twice. In the spring of 1942 leakage developed and when the pipe was uncovered it was found to be in bad condition. Pending replacement, repairs were made and seventeen zinc anodes were installed with series-parallel connections. In the press of other work, this replacement job was put aside and in 1943 it was found that no further leaks had developed. In 1948 the replacement had still not been made and we were getting a good potential-to-ground and plenty of protective current. The last test made in the spring of 1950 shows a slight increase in the potential-to-ground and the pipe has not been replaced nor have we felt it even necessary to uncover it for visual inspection."

The graph at right provides additional evidence from the State of Texas. Here are two examples, under widely dissimilar conditions, where zinc has proved itself as a highly efficient cathodic protector for underground pipe lines. This is not surprising in view of the long-recognized superiority of the metal in the field of galvanizing.



EFFECT OF ZINC ANODE PROTECTION ON OLD LINES. Most of the United Gas Corp.'s welded-steel-gas distribution mains, coated with hot asphalt and asbestos wrapper, were installed before 1930. Cathodic protection of mains with zinc anodes was completed in early 1944. Curve shows cumulative leak record of these mains. Only 5 corrosion leaks occurred in the 6 years since cathodic protection was applied, comparing with 142 during 1932-1944.

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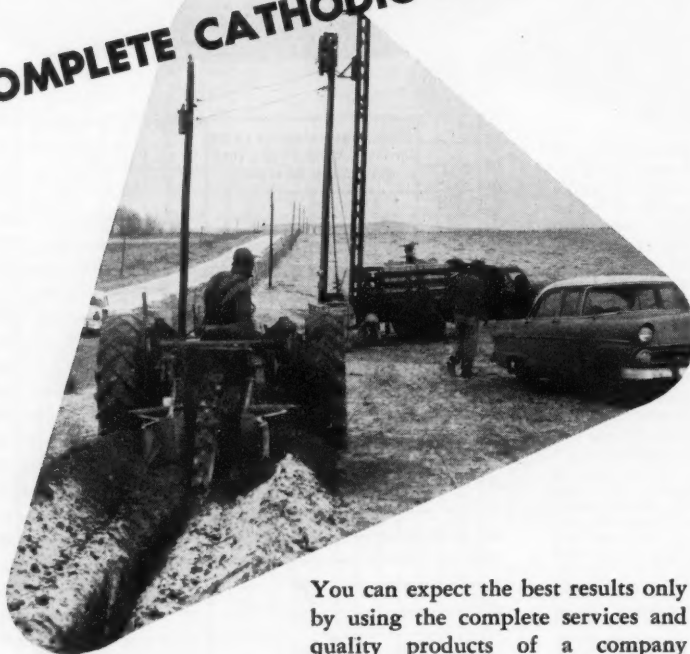
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nitrogen was studied at elevated temperatures (600 to 1300C). Zirconium heated in air formed first a black oxide which was superseded by a white scale after times which were dependent on the scaling temperature. No change in scale color was observed during isothermal runs in pure oxygen and in pure nitrogen; however, specimens heated in mixtures of the two gases showed the same color change as in air. X-ray patterns of the black scale formed in air revealed monoclinic and tetragonal zirconium dioxide with possibly some lines of zirconium nitride; the white scale consisted of both forms of zirconium dioxide. Scales formed in pure oxygen were composed of both forms of zirconium dioxide, while those formed in nitrogen revealed

zirconium nitride. Heating zirconium in air below 1050C caused considerable lateral dimensional increases of the metal. This phenomenon did not set in immediately but required a definite time to start. Growth of the metal also was observed in the oxygen plus nitrogen mixtures, but not in the pure gases. During isothermal runs in air up to 1050C the initial parabolic or cubic rate was followed by a sharply increased scaling rate. The same behavior was observed in oxygen plus nitrogen mixtures but not in the pure gases where a quasi-parabolic rate was observed. The time at which the deviation from the first law occurred was found to be dependent on the composition of the atmosphere. (auth).—NSA. 10119

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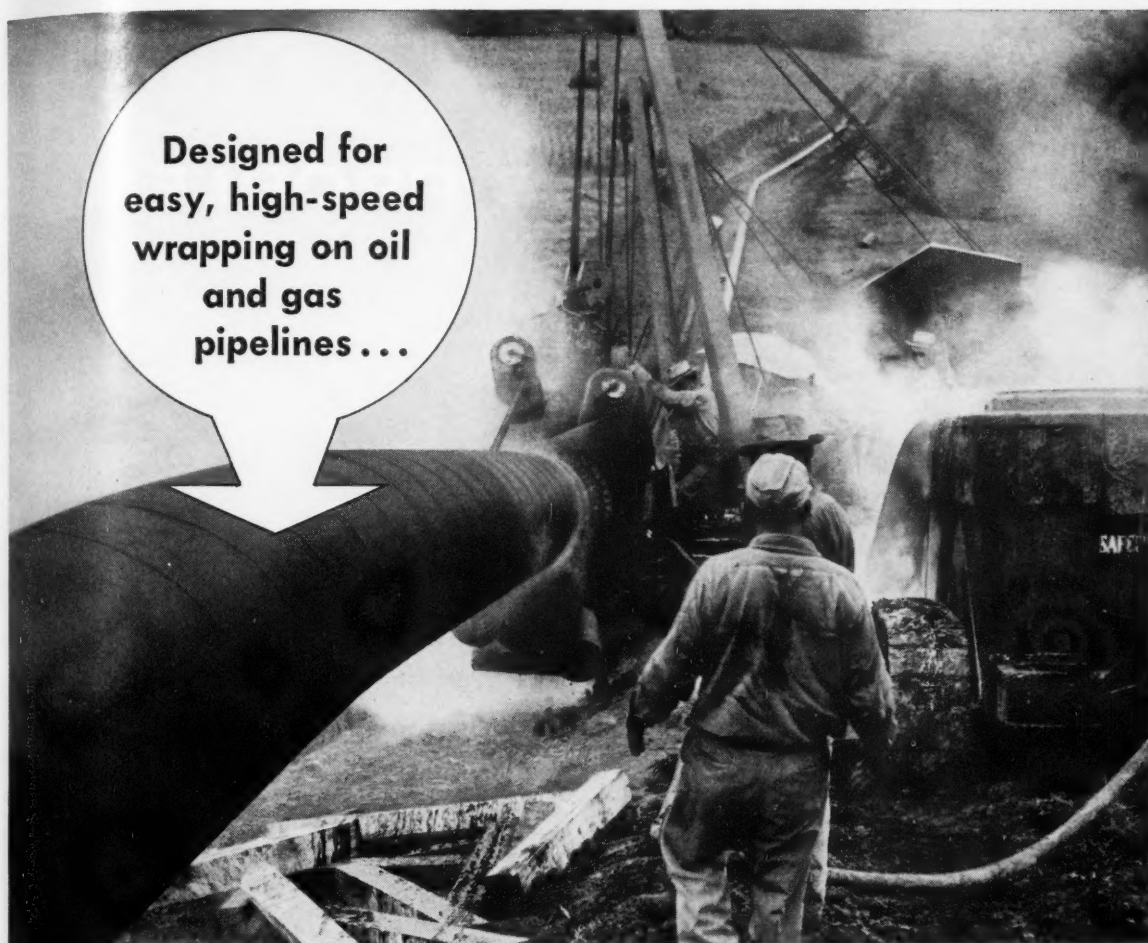
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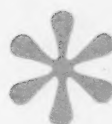
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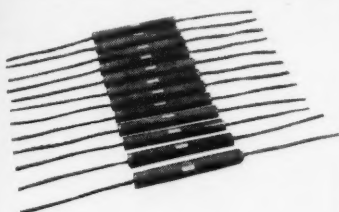
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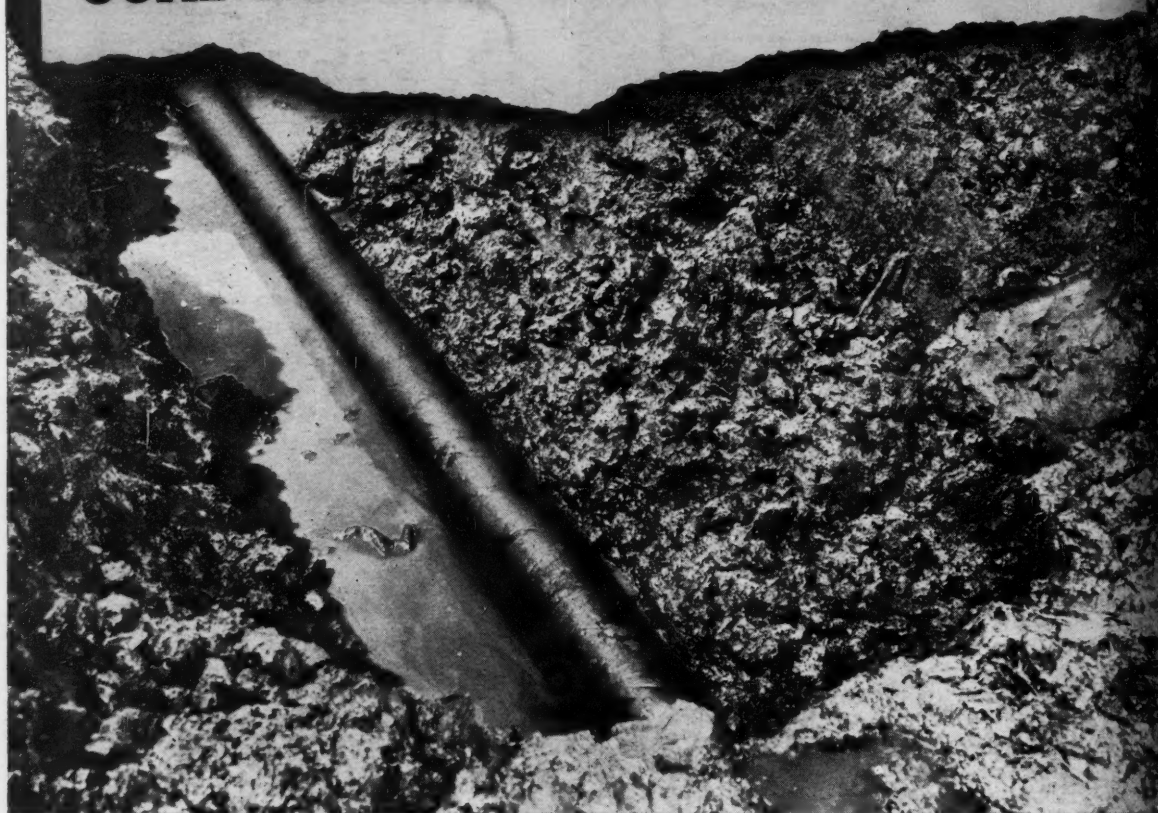
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